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AN OPTIMIZED APPROACH FOR THE DEVELOPMENT OF HIERARCHICAL ENERGY INTEGRATION WITH MULTIPLE ENERGY RESOURCES AND EMPHASIZING THE HEURISTIC TECHNIQUES

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ABSTRACT

Traditionally, electricity has been produced at massive central power plants and distributed to consumers via transmission and distribution systems. However, dispersed generation is quickly becoming the norm. It is called distributed generation when several individual generators are linked together at the distribution level, near the end user. However, this raises new research questions for engineers to consider. Protection and control, self-excitation, and isolation are only a few examples of the difficulties that can arise. In order to investigate these concerns thoroughly, engineers must first configure the foundational simulation model to correctly reflect the distributed generation system. Various renewable energy sources, including wind tubines (Type 1 with soft starter capability and Type 3 based on a synchronous generator), solar panels (Photovoltaic Array), and small hydroelectric dams (Synchronous Generator), are evaluated and rated for use in the construction of a microgrid. Here hierarchical methods with heuristic techniques such as harmony search algorithm, simulated annealing algorithm are considered and these algorithms based optimized controllers are used for controlling the real and reactive power of various energy sources. This model was created digitally using PSCAD/EMTDC.

Keywords: *hierarchical methods, multiple energy sources, protection, heuristic techniques, optimized controllers, simulation.*

1. INTRODUCTION

In recent years, renewable energy sources (RES) have gained widespread recognition as viable solutions for meeting the electrical demands of microgrids [1]. Researchers and specialists in the field of electrical energy have recently become more interested in the design and development of microgrids

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that are powered by renewable energy sources. Traditional energy sources (nuclear, coal, oil, and gas based) have higher operating costs than renewable ones (wind, solar PV, fuel cells, biomass, etc.). Because of their low environmental impact, smart and microgrid developers and planners give preference to renewable energy sources. Since people are starting to worry more about the environment and using more electricity, renewable energy sources have risen to the top of the energy food chain. Microgrids allow for the incorporation of decentralized energy sources that are inherently more reliable. The bus voltage determines whether a microgrid is categorized as AC, DC, or hybrid. The AC vs. DC power dispute has been going on for as long as there have been power grids. When compared to an AC microgrid, DC microgrids have many benefits. DC microgrids allow for the integration of most renewable sources, including solar PV, with fewer stages of conversion. Capturing and storing energy

Elements connected to a DC microgrid will only need a single DC-DC converter. Consequently, a DC microgrid will improve overall efficiency more than an AC microgrid. In addition, LV DC microgrids have the added benefit of reducing the potential for harmful electric shock. DC power is used by the vast majority of today's electronic loads, including LED lighting, telecommunications gear, electric vehicles (EVs), and heating, ventilation, and air conditioning (HVAC) systems. DC microgrids are widely used in commercial and government structures, data centers, telecom and broadcasting hubs, spacecraft, ships, rural electrification systems, and electric vehicle charging stations. Even though DC microgrids appear promising, their development is hampered by the lack of codified standards and regulations.

For a DC microgrid [2] powered by an unreliable energy source, energy management and control are crucial. In the face of a wide range of disruptions, the microgrid can continue to function reliably for an effective energy management and control architecture. In this paper a bus is connected with Wind turbine of Type 1 kind with soft-starting capability, Solar Energy (Photovoltaic Array), Synchronous Generator (Small Hydro), Type 3 DFIG based Wind Turbine [3].

2. ENERGY SOURCES

In these days power usage has increased a lot and if it is to be reached to load then controlling and maintaining quality is very important and quality without interruption is required for this purpose we use different renewable energy sources, some of them are discussed here.

2.1 Solar Energy (Photovoltaic Array):

The term "solar energy" is used to describe power that is de-rived from the sun. With the use of a photovoltaic cell, solar energy can be directly transformed into electricity via the photo voltaic effect (PV cell) [7]. When it comes to distributed generation, solar energy with PV cells is a close second to wind power. Microgrids often employ PV arrays as its DER components. In Fig. 1, we see a simplified equivalent circuit model of the cell module's electrical behaviour. Equation gives the current drawn from a PV module.

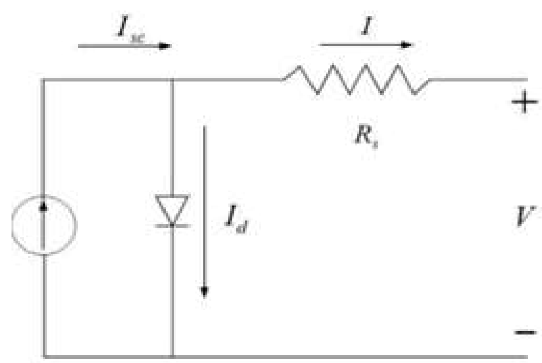

Fig1: Equivalent circuit of PV module

$$I = I_{sc} - I_d = I_{sc} - I_0[\exp\left(\frac{V + IR_s}{nV_T}\right) - 1]$$

Where as
I= output current of PV module(A)
I_d = diode current (A)
I_{sc}= short circuit current of PV module(A)
Io= diode saturation current(A)
V = terminal voltage of PV module (V)
Rs = series resistance(ohm)
n= ideal constant of diode (1~2)
V_T = thermal potential of PV module(V)

A DC/DC converter is typically connected to a photovoltaic array, and its job is to increase the array's output voltage by an appropriate amount. The maximum power point tracking (MPPT) function is an example of an advanced and optimized technique that might be implemented for a PV array through the control of a DC/DC converter. Here in this paper hierarchical methods are used to get optimized output. Other potential applications include dynamic voltage and current control. An inverter is required to change the direct current (DC) output of a PV array into alternating current (AC) output before the PV array can be connected to an AC grid system. Studies on microgrids are being conducted, and these studies require either hardware test facilities or software simulation testbeds. This is due to the fact that the microgrid is a novel and developing concept. In this paper this solar panel developed in PSCAD is shown in fig 2.

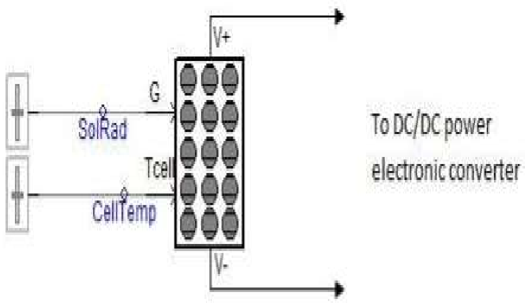

Fig 2 solar panel

We are able to conduct additional research and studies on microgrids as a result of implementing a simulation model of a microgrid that includes models of renewable energy sources.

2.2 Wind farm:

A device that is capable of converting the kinetic energy of wind into electrical energy is called a wind turbine. There are presently over 650 gigawatts of power being produced by hundreds of thousands of big turbines that are installed in locations that are known as wind farms. Each year, an additional 60 gigawatts of power is added. Wind turbines are becoming an increasingly important source of intermittent renewable energy. These turbines are employed in many nations to minimize reliance on fossil fuels and to bring down the overall cost of energy production [6].

2.2.1 Wind turbine of Type 1 kind with soft-starting capability:

The great majority of wind turbines across the globe are fitted with induction generators that are able to connect to the grid. It is recommended to employ single phase or three-phase squirrel cage rotor type induction generators rather than synchronous generators due to the cost-effectiveness, robustness, compactness, ruggedness, low inertia, and the requirement for minimum maintenance offered by these types of generators. Three-phase induction generators see widespread application in the field of large-scale distributed power delivery.

Wind turbines with an induction generator that are directly connected to the supply must typically have a soft starter installed in order to limit the massive inrush current to the supply and to connect the system smoothly to the grid without causing massive mechanical shocks or vibrations that could damage the gear box, bearings, and couplings. It employs a soft starter that is based on thyristors. The generator has a capacity of 25 kVA and has a line voltage of 0.6 kV and a frequency of 60 hertz (Hz). The input torque (T=0.8 PU) to the generator is a representation of the wind turbine shown in fig 3 as PSCAD model.

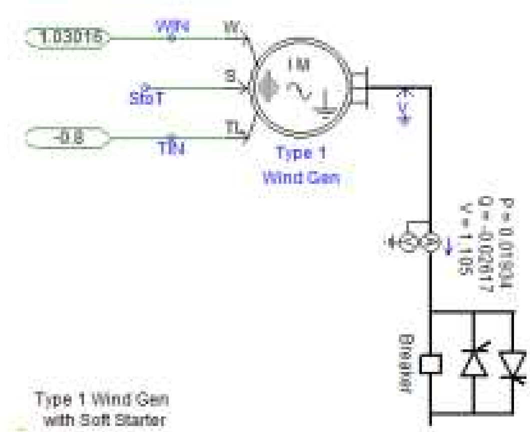

Fig 3: Type1 wind turbine (soft starting capability)

2.2.2 Wind Turbine Based on Type 3 DFIG:

This particular wind turbine utilizes a doubly-fed wound-rotor induction generator and has changeable speeds. Wind turbines typically make use of a device known as the doubly-fed induction generator (DFIG), which combines the back-to-back converter with itself. The turning speeds of traditional wind turbines are predetermined, however DFIG technology makes it possible for wind turbines to operate at a wide variety of speeds. The back-to-back converter is attached to the rotor of the DFIG, and its job is to provide currents of changing frequencies to the rotor so that the DFIG can achieve the speeds that are wanted for the rotor. This application note presents a demonstration of the utilization of a back-to-back converter controller in conjunction with a DFIG wind turbine [8]. The simulation instances that are described in this document cover the dynamic reaction of DFIG throughout the process of turbine braking and to variations in wind speed.

The power that the wind possesses in the form of kinetic energy is denoted by the symbol Pv and can be calculated as follows:

$$P_v = \frac{1}{2}\rho\pi R^2 V_v^3$$

Where

V_v is the average wind speed in the swept area

$A = \pi R^2$, R is the diameter is the rotor blade and ρ is the air density.

In this paper the generator has a capacity of 100 kVA and has a line voltage of 0.6 kV. It has a frequency of 60 hertz and operates at that voltage. The input torque, denoted by T = -0.25 PU, to the generator is a representation of the wind turbine. Reactive power can be given to the machine through the rotor by utilizing power electronics in some configurations. As a result, there is no requirement to pull any reactive power from the system while it is starting up

2.3 Synchronous Generator (Small Hydro):

The mechanical energy produced by the turbine is transferred to the electric generator, where it is transformed into electrical energy. The rotor and the stator make up the two primary elements that make up the generator. The mechanical torque that is delivered by the turbine shaft is applied to the rotor, which is the spinning component that makes up the rotor. Magnetizing the rotor, also known as "exciting" it, causes a voltage to be induced in the component that is stationary, known as the stator. The exciter-regulator is the primary control mechanism of the generator. It is responsible for setting the output voltage and maintaining its stability. Except in cases when the generator is geared with a speed increaser, the speed of the generator is decided by the selection of the turbine. In general, for a given amount of power, a decrease in speed will result in an increase in the physical size of the generator as well as an increase in its overall cost [9].

A tiny hydro turbine is used to drive a synchronous generator, and the turbine is set up to function at its rated conditions from the beginning. The governor is responsible for regulating the quantity of power that is produced by the turbine. The line voltage of the synchronous generator is 0.6 kV, and the frequency of the generator is 60 hertz. The generator has a rating of 0.12 MVA. An exciter, which is responsible for magnetizing the device, is connected to the field windings of the machine. As a result, the system will not have any reactive power extracted from it.

Table 1 real and reactive power initialization

Energy sources	P(KW)	Q(KVAR)
Type1 WT	19.34	26.17
Type2 WT(DFIG)	59.82	7.644
Solar Power	21.83	0.302
Synchronous Gen	90.92	39.54

3. DESCRIPTION OF THE PROBLEM

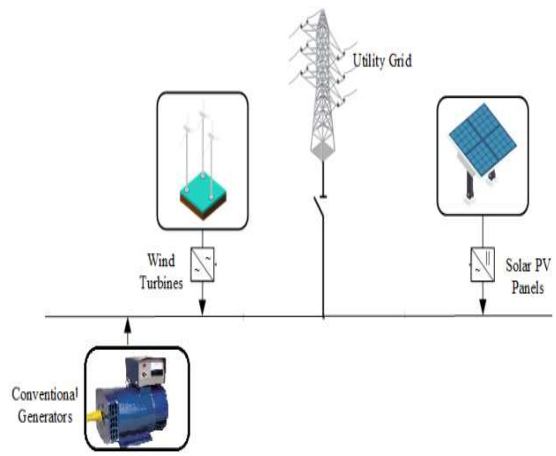

Fig 4 schematic with connections

The environment, the economy, and technology all stand to benefit from the use of microgrids is shown in fig 4. The utilization of RES leads to a reduction in both the carbon footprint and other emissions caused by the combustion of fossil fuels. The reduction in losses and emissions brings about a general cost savings across the board. On the other hand, the technological benefits include supplying electricity to previously powerless areas and lowering the likelihood of power interruptions occurring [10].

The grid following inverters are current-controlled sources that regulate the power output by sensing the grid voltage angle through the utilization of the Phase-Locked Loop (PLL). They do nothing more than adhere to the grid angle or the grid frequency. Therefore, they must function in a mode that is connected to the grid or utilize a DG unit that is capable of regulating the voltage and frequency of the microgrid. Grid forming inverters, on the other hand, are voltage-controlled sources that regulate the voltage and frequency output of the microgrid; as a result, they are able to be operated in islanded mode. The grid forming sources serve to lessen the dependency of frequency dynamics on the mechanical inertia that is present in the system, which in turn contributes to the grid's increased stability. In order to extract the frequency and voltage commands from the measured active and reactive power from the DG unit, droop control is typically utilized in grid-forming inverters. These inverters then employ these commands to manage the output voltage and frequency

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For this paper a 0.6KV bus is considered, where utility grid is utilized, to help get us to a more sustainable energy system, we've created a hierarchy of energy sources called the Energy Hierarchy. It takes a sequential, waste-hierarchy-like method to reducing resource consumption. Prevention of wasteful energy use is a top priority, and this can be achieved through increased energy efficiency and the reduction of inefficient practices. The second top priority is the environmentally responsible generation of energy sources. Options for producing energy that are both depleting and wasteful are given the least importance.

In this paper the model developed by PSCAD/EMTDC software and analysed for the ratings are given below

In this paper it is observed that the distributed generation system that has a voltage rating of 0.6 kV. Through the use of a step-up transformer rated at 0.6/115 kV, the distribution network is linked to a high-voltage network with a rating of 115 kV is considered. The models are set up with the following active (P) and reactive (Q) power, which may be found in Table 1.

4. EXAMINING THE RESULTS

The first type of renewable energy comes from the environment itself, such as the sun, the wind, the waves, the tides, and the rain (hydropower). This class also includes energy derived from the heat of the Earth's core (geothermal energy).
Considering that these resources all come from the sun, whose lifespan is estimated at 6.5 billion years, they are considered infinite. Because of the this features hierarchical techniques is considered for getting uninterruptable quality power to consumer. Due to this a model is developed with intelligent controllers using PSCAD/EMTDC software

4.1 PSCAD/EMTDC Software

PSCAD facilitates effortless system construction, simulation, and modelling, opening up a world of simulation opportunities for power systems with intelligent controllers. The model shown in fig5.

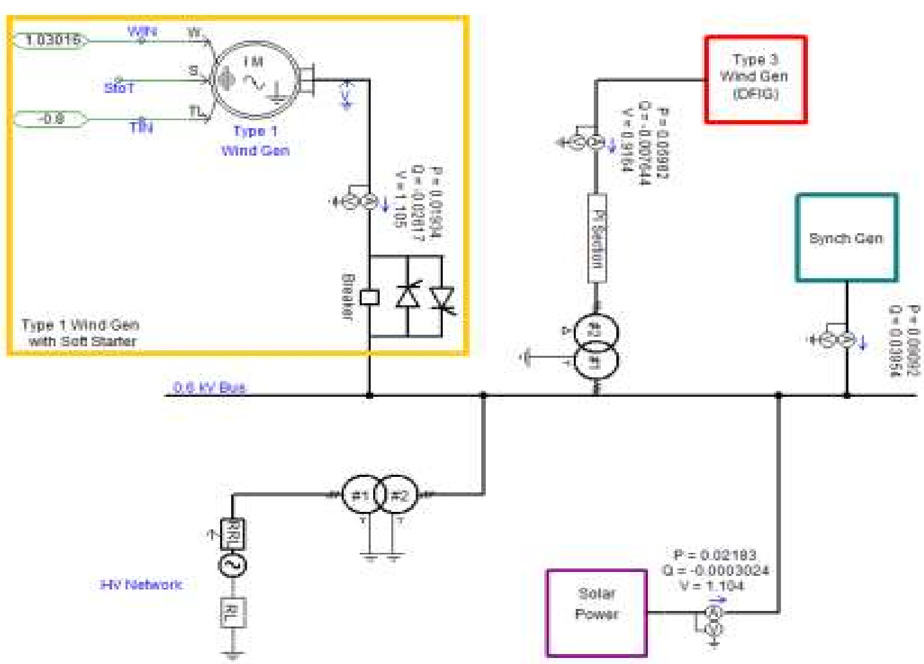

Fig5 A hierarchical model of energy sources

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4.1.1 Synchronous generator used for small hydro stations:

The angular speed, real and reactive power for the synchronous generator shown in fig 6(a), (b), (c).

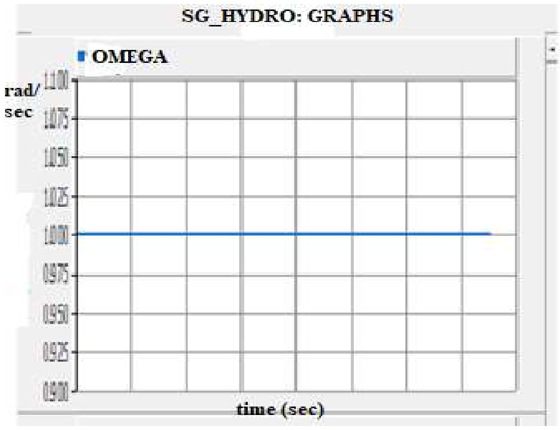

Fig6(a) angular speed of synchronous generator

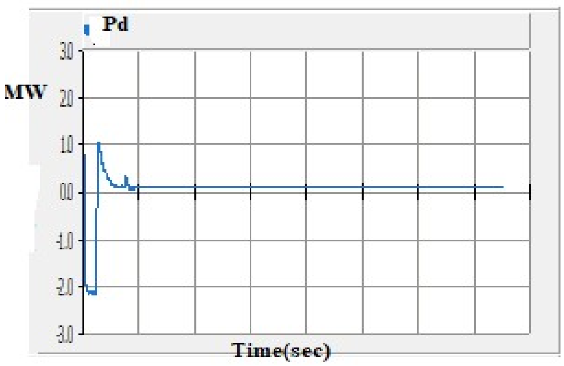

Fig6(b) real power of synchronous generator

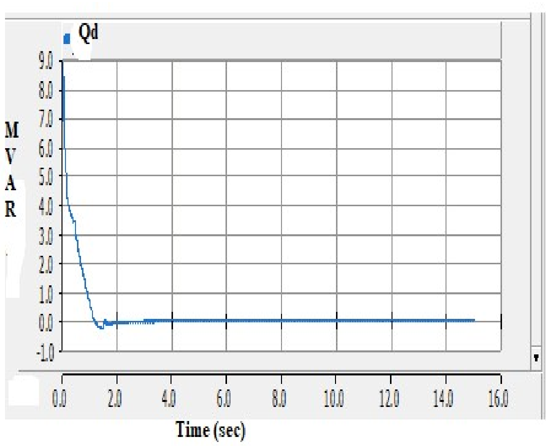

Fig6(c) reactive power of synchronous generator

Similarly, the solar panel and type 1, type 2 wind turbines speed and operating constraints are shown fig7, fig8. With this an ac micro grid having 0.6KV bus with a step- up transformer is under analysis can obtained. From this analysis, in this paper it is clear that for different type of renewable energy sources. Especially for solar panel angle of the position of the solar panel and DC voltage output for DC-DC converter is also shown in fig 9.

For this microgrid the bus is not connected to load and this proposed modal is applicable for industries and agriculture etc., next the below results for different sources used for the distributing for the load and getting the analysis of the system.

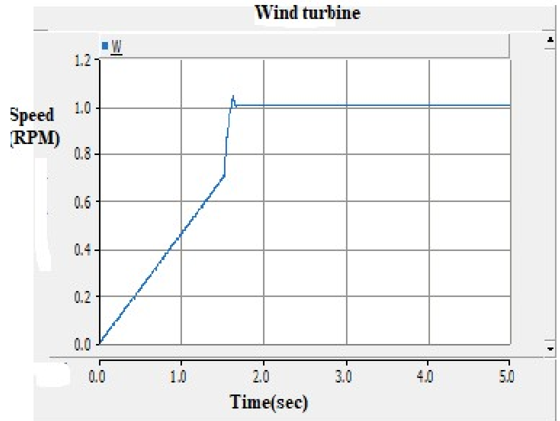

Fig7: speed of the wind turbine

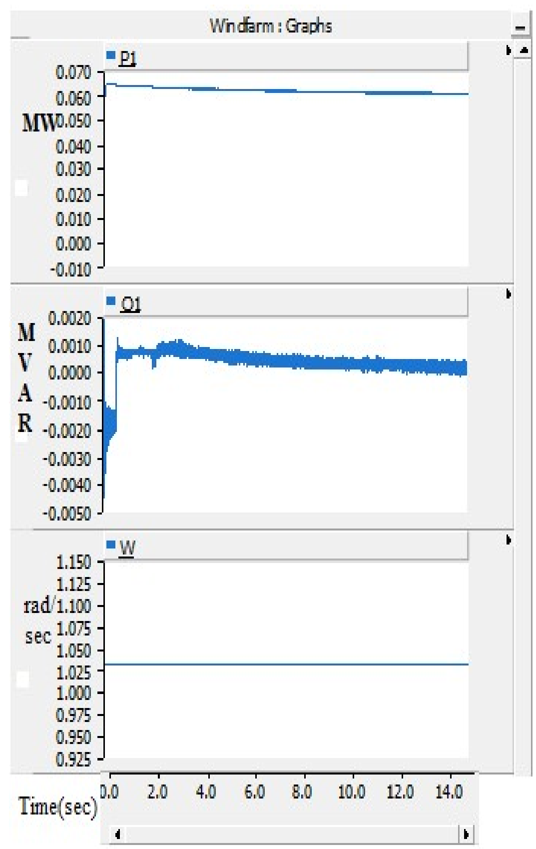

Fig8: operating constraints

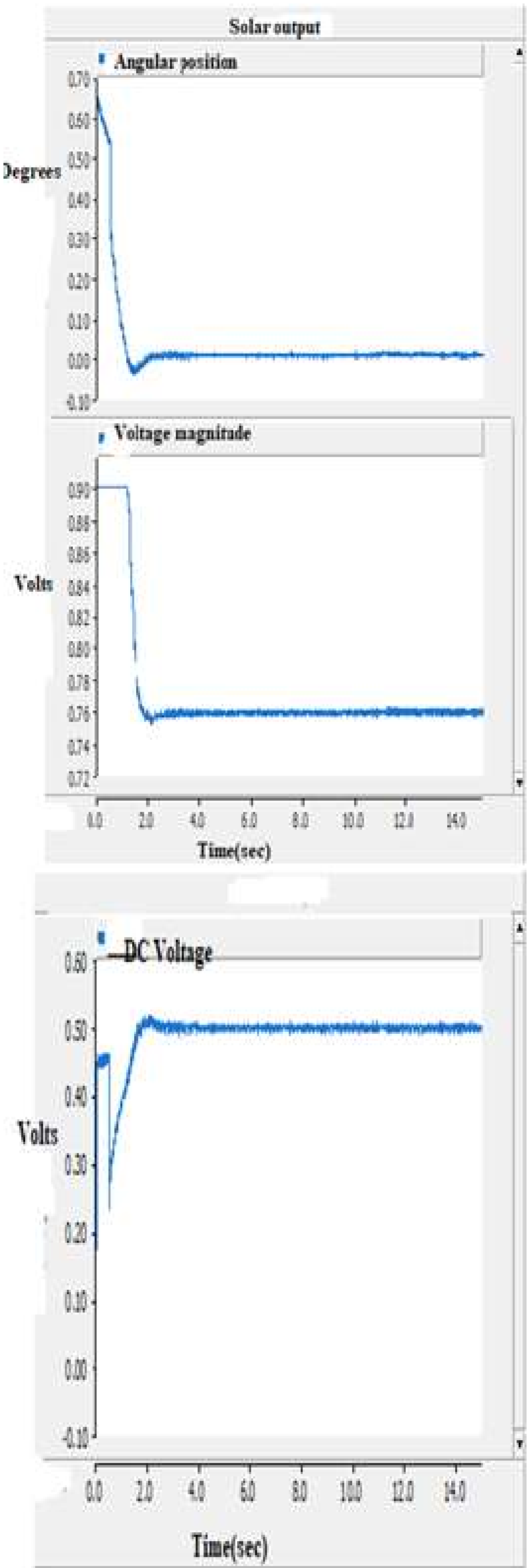

Fig 9: angular position of solar panel and output voltage

5. CONCLUSION

Microgrids are currently being considered a promising option for the integration of distributed generation (DG) systems into the utility grid. The implementation of hierarchical methods of this solution will result in a decreased reliance on fossil fuels and an increase in the optimized effectiveness of the electric grid in its whole. In this article, a discussion is offered on the microgrid modelling and operation modes that are currently available. The microgrid serves as an important point of connection between decentralized power generation and various renewable energy sources. Isolated modes, in which the microgrid functions independently of the larger grid, as well as grid-connected modes, are also possible. The many strategies for enhancing the level of stability are illustrated and the foregoing investigation leads one to the conclusion that Micro Grid end-users and the grid as a whole can both benefit from the aggregation of DG sources using an optimized Controller, which aids in the optimal cooperation of the DG sources and allows for the development of functions for special issues like voltage, real and reactive power control. In contrast to the standard grid, the microgrid operates in an unpredictable and intermittent manner. This article illustrates a variety of microgrid structures, as well as comparative assessments of those systems. There is discussion of a variety of optimal control systems, including fundamental control schemes such as centralized, decentralized, and distributed control, as well as multilevel control schemes such as hierarchical control .

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