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Dynamic Stability Issues with a Grid Connected Microgrid System

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ABSTRACT

The hybrid energy system (solar, wind and diesel) is a good way to supply the electricityfor some remote places that are hard to connect to the power grid and some areas wherestorms and other catastrophic events cause long-term power outages from power grid. Whatis more, in order to control the global warming and reduce the pollutant emissions, changingfuelpowergenerationto renewable power generation issignificant. In this paper, a grid-connected Microgrid (MG) system including two popular renewable energy resources which are solar Photovoltaic (PV) and wind generators have been studied. For improving the dynamic stability of a grid connected MG system, a Battery Energy Storage System (BESS) is connected at the AC side of the power grid that can control and compensate both the active power and reactive power to the load demand. Also in this paper, the MPPT of the PV system and the controller of the Grid Side Converter (GSC) based on Adaptive Neuro-Fuzzy Inference System (ANFIS) algorithm to maintain the voltage and frequency of system are concentrated. Simulation results performed using MATLAB/Simulink platform in time-domain are shown to evaluate the effectiveness of the designed controllers. It can be concluded based on the simulation results that the proposed ANFIS controllers can be applied to enhance the voltage stability of the studied grid-connected MG system.

1. INTRODUCTION

Dynamic stability is an important aspect of microgrid systems that are connected to the grid. It refers to the ability of the system to maintain stable voltage and frequency levels in the face of changes in load or generation. Dynamic stability issues can arise due to a number of factors, such as the interaction between the microgrid and the grid, the presence of distributed energy resources (DERs), and the control strategies used in the system.One common dynamic stability issue with grid-connected microgrid systems is the occurrence of voltage fluctuations. When a DER such as a solar panel or wind turbine is connected to the microgrid, it can cause voltage fluctuations due to its intermittent nature. These fluctuations can affect the stability of the microgrid and the grid it is connected to, leading to power quality issues such as flicker and harmonics.Another issue is frequency instability, which can occur when the microgrid is not able to maintain a stable frequency due to changes in load or generation. This can result in a loss of synchronization with the grid and potentially lead to blackouts. To overcome this problem, we introduce some control strategies to overcome dynamic stability issues with a grid-connected microgrid system. Some of these include Improved Control Strategies: Advanced control strategies can be implemented to improve the stability of themicrogrid system. These can include droop control, virtual inertia, and advanced power electronics such as FACTS (Flexible AC Transmission Systems) devices.Energy Storage: Energy storage systems such as batteries, flywheels, or supercapacitors can be used to regulate the voltage and frequency of the microgrid system. Energy storage can also be used to provide backup power during blackouts or other power interruptions. In this project we introduced battery storage system to the model for balancing the dynamic issues occurred in the grid.

2.MICROGRID:

Microgrid system is a combination of two or more renewable energy sources which are connected to the grid, which is also known as hybrid power. The hybrid systems provide better performance compared to a single source system. Hybrid AC/DC MG combines advantages of both AC and DC power systems that can integrate DC renewable generation, storage, and building electrical loads easier and more efficiently than conventional AC based systems.

The performance of a hybrid building MG coupling on-site PV system with AC and DC loads is tested. Renewable energy resources such as solar, wind, geothermal, hydropower and tidal energy are reliable, plentiful and will potentially be very cheap once technology and infrastructure improve.

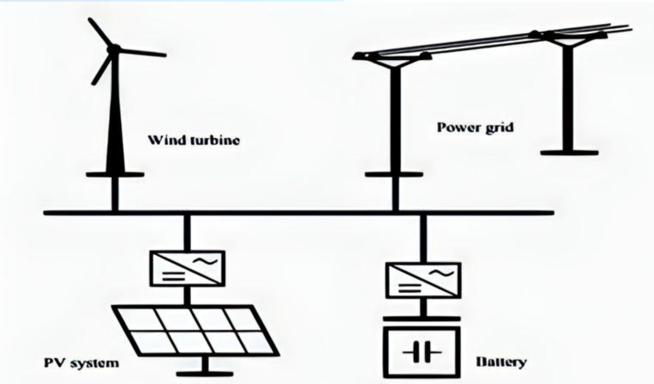
For improving the power quality of feed-in grid current in a grid-connected MG that can be influenced by a distorted utility grid, a feed-in grid current resonant controller-based harmonic compensation loop is integrated to the original autonomous current sharing controller that can effectively reduce the system equivalent output admittance at selected harmonic frequencies.

Thus, the total harmonic distortion of the feed-in grid current can be significantly decreased. In a novel voltage-based controller for frequency control in inverter-based isolated MGs through load voltage regulation was proposed with only requires a local feedback signal. For continuous supply power to the loads, BESS is suggested to install in the MG system.

In an intelligent battery management system (IBMS) considers a fuzzy controller used in Home Microgrid which is composed by a PV generator, Battery system and a small residential group working in a grid-connected and island mode. However, in an MG that consists of both AC and DC sources. A bi-directional AC/DC converter is used to link the AC and DC by regulating the power between them. The model and control strategy of each module were analyzed and the simulation test-bed using MATLAB/Simulink has been studied in .

In this research, the operation characteristics and transient process of grid-connected operation under different conditions were presented. Ina hybrid MG system has been taken into consideration with a Battery Energy Storage System (BESS) is connected at the DC side of the Grid Side Converter (GSC) that helps to control and compensate both the active and reactive power according to the load demand.

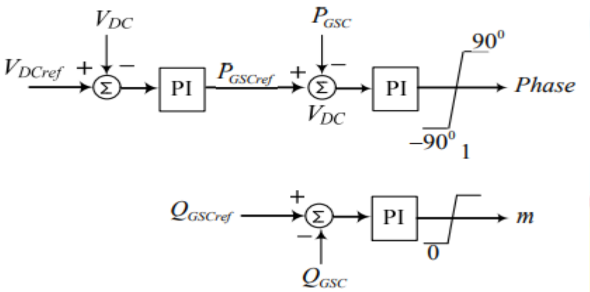
First, solar and wind resources vary widely in different places. In a hybrid energy system, the power proportion of wind, solar and diesel affects the reliability and economy of the system. In order to build a solar-wind-diesel hybrid system that can supply stable power and cost as little as possible, it is necessary to optimize and simulate the system.



MICROGRID SYSTEM

3. DESIGN ANFIS CONTROLLER FOR GSC OF MG

The GSC manages the power of the whole MG system. It stores the surplus active power in BESS during light load conditions and feeds power during power deficit. Moreover, GSC also compensates the required amount of reactive power to keep the system voltage constant during load fluctuation. In state-of-the-art systems, cascaded voltage control is often implemented in order to control the GSC of MG. Fig. 4 shows the block diagram of GSC with classical cascade control. In this control scheme, the currents of the converter are controlled directly by means of the inner control loops. The outer control loops control the active power, or DC link voltage and reactive power.



The basic principle of the current controlled of GSC is to control the instantaneous active and reactive grid currents independently and hence provide unity power factor. Besides independent control of active power (P) and reactive power (Q), this kind of converter can mitigate the power fluctuation by absorbing/releasing the unbalanced energy at AC/DC side. However, with this method, the considerable number of feedback signals required (two ac line currents, two ac line voltage signals and a DC bus voltage signal) are associated with the extra cost of sensing devices and slow dynamics of the outer DC regulation loop is other backward of this method. In this paper, the proposed ANFIS controllers are used to replace PI controllers in GSC of PV system. An ANFIS controller that is a class of adaptive multi-layer feedforward networks it combines the self-learning ability of neural network with the linguistic expression function of fuzzy inference is designed. Fig. shows the structure of the ANFIS controller

As shown in Fig, the ANFIS' structure is similar to a neural network, which maps inputs through dependent functions to corresponding parameters, and then through output functions with corresponding parameters that produce outputs that can be used to explain I/O mapping. The parameters corresponding to the dependent function will change through the learning process. Calculating these parameters is easy with the gradient vector that sets the limit in a good way for the fuzzy inference system modelled data into/out according to a set of parameters. The ANFIS network is composed of five layers with the following equations representing the output function of each layer:

$$O_i^1 = \mu A_i(In_1),\ i=1\div2 \quad \text{or} \quad O_i^1 = \mu B_{i-2}(In_2),\ i=3\div4 \tag{3}$$

$$O_i^2 = w_i = \mu A_i(In_1).B_i(In_2),\ i=1\div2 \tag{4}$$

$$O_i^3 = \overline{w}_i = \frac{w_i}{w_1+w_2},\ i=1\div2 \tag{5}$$

$$O_i^4 = \overline{w}_i z_i = \overline{w}_i(a_i.e+b_i.\Delta e+c_i),\ i=1\div2 \tag{6}$$

$$O_i^5 = F = \sum \overline{w}_i z_i,\ i=1\div2 \tag{7}$$

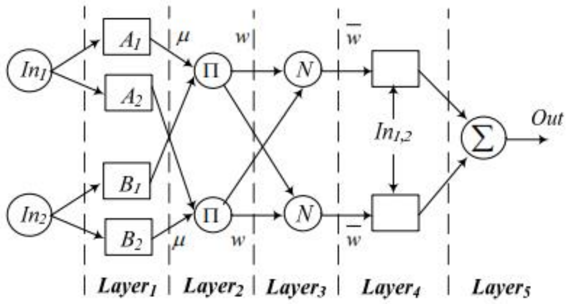


Fig. 5. Structure of the ANFI

4.BATTERY

In this thesis, the ZESS50 battery that is made by ZBB company will be used to build
the hybrid power system. The follows are some basic parameters of the battery (Homer,
2014).

Nominal capacity: 50kWh
Nominal voltage: 100V
Nominal capacity: 500Ah
Round trip efficiency: 72%
Max charge current: 150A
Max discharge current:300A
Lifetime: 30 years
Cell stack lifetime: 10 years

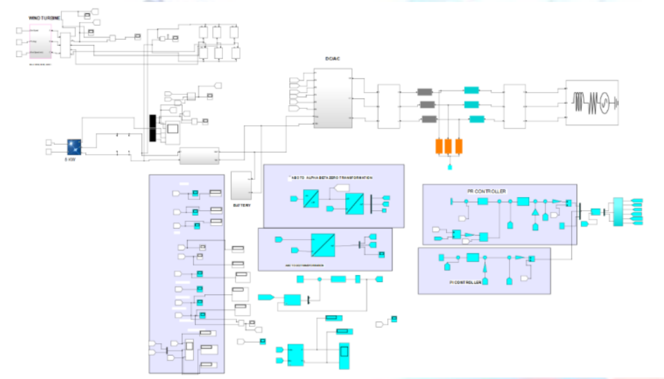
The cost of a ZESS50 battery is 8000 dollars, the cell stack replacement cost 25% of thecapital cost. The quantity of battery that will be considered is 0, 5, 10, 11, 12, 13, 14, 15, 16,17, 18, 19, 20, 21, and 22.

5. CONVERTER

Any system that contains both AC and DC elements requires a converter. A converter canbean inverter (DCtoAC)and rectifier (ACto DC).In this model we designed a boost converter to boost up the output value of the solar panel

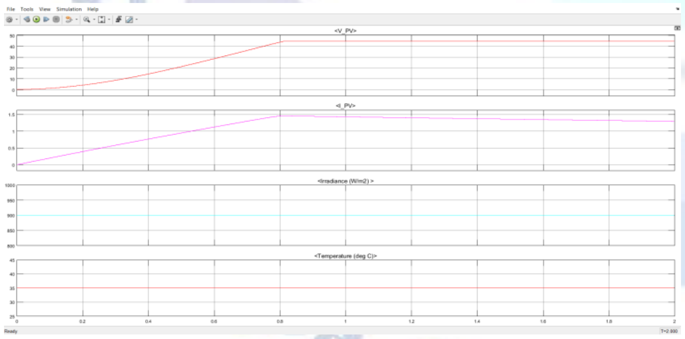
In this thesis, the efficiency of inverter is set 90%, the efficiency of rectifier is set 85%,lifetime is 15 years. The capital cost of converter is 100 dollars per kW, the operating andmaintenance cost is 2 dollars per kW per year. The size of converter that will be considered is50kW, 60kW, 70kW, 80kW, 90kW, 100kW, 110kW, and 120kW.

Simulation diagram:

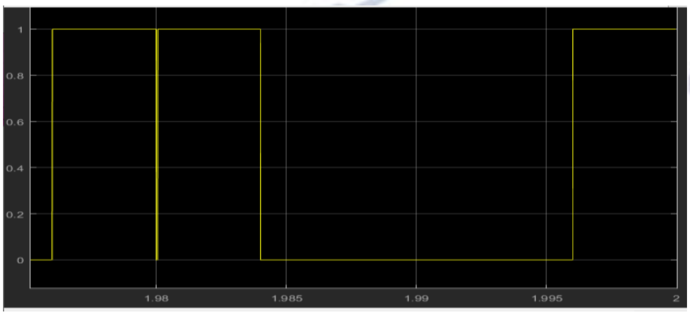


Simulation results:

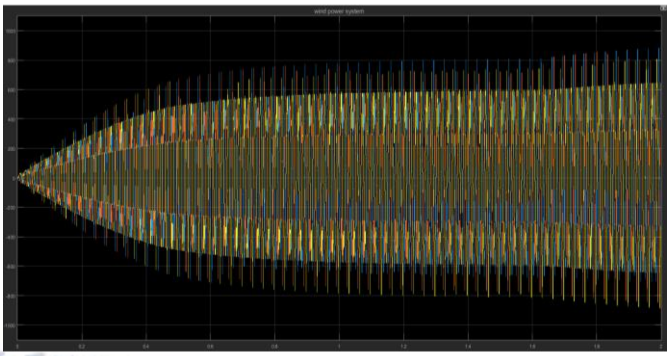
PV OUTPUTS



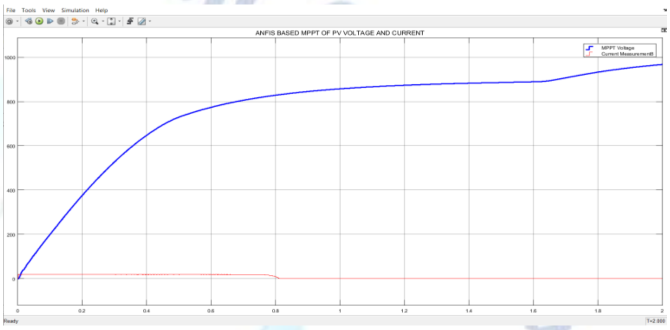
ADAPTIVE NEURO FUZZY ALGORITHM :



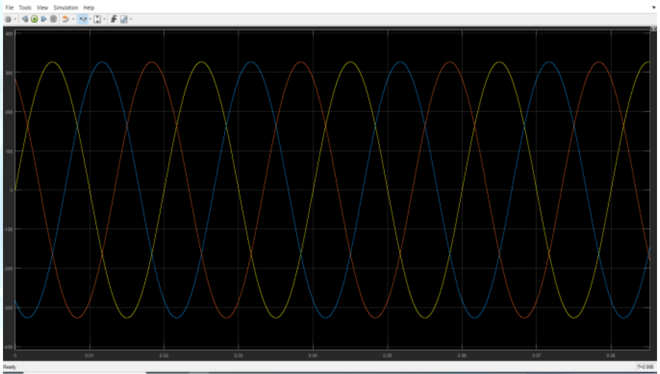
TURBINE OUTPUT VOLTAGE :



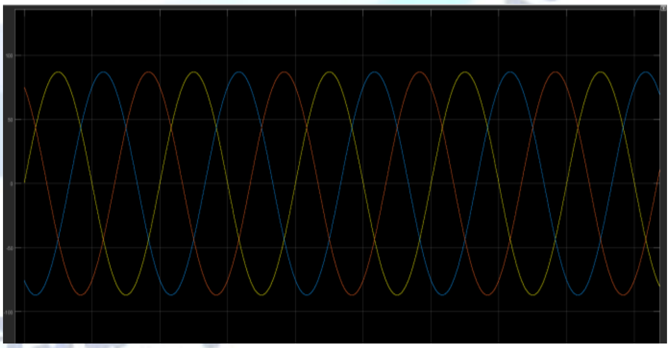
DC TO DC CONVERTER :



THREE PHASE OUTPUT VOLTAGE:



OUTPUT CURRENT:



7. CONCLUSION

In this paper, a hybrid renewable power system is designed to supply electricity for 20 households. Firstly, the load analysis is made in different time periods and different seasons. Secondly, the solar and wind speed data is collected. Thirdly, the structure of hybrid renewable power system is built and the parameter and price of component parts are discussed. Fourthly, different sizes or quantity of component parts form different schemes of the system. Then, the optimization method is introduced, the first step is to filter the qualified schemes that meet the requirements of system operation, the second step is to rank these qualified schemes with the net present cost.

From the results of the analysis, compared with sole renewable power system, PV- wind-diesel-battery hybrid power system has a good power supply quality and the lowest total NPC, COE. Because of the complementarity of solar and wind, the PV-wind-diesel-battery hybrid power system has a better economic effect than PV-diesel-battery hybrid power system and wind-diesel-battery hybrid power system. As a consequence, the hybrid power system that constitutes of 200kW PV, 13×10 kW wind turbine, 60kW diesel generator, 17×50 kWh Battery and 100kW Converter is the optimal choice for the 20 households in Lexington, Kentucky. From the result of simulation, this system meets the electric requirements well.

In the paper, this hybrid renewable power generation system has been proved to meet the remote place off-grid electricity requirements. For some places where storms and other catastrophic events cause long-term power outages from grid power, this hybrid renewable power generation system is a good way to supply the electricity. What is more, in order to control the global warming and reduce the pollutant emissions, changing fuel power generation to renewable power generation is significant. Diesel generator is always the alternate energy solutions and power supply solutions of islands. But the diesel generator has a big problem of pollutant emissions. The pollutant emission comparison between diesel system and hybrid system proves that the power system designed in this thesis is a very good way to alleviate the global pollution problem.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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