Embedded Selforganizing Systems (Vol 9. No 1. 2022) (pp. 15-19)

Embedded Selforganizing Systems

Issue Topic: "Advances in Smart Technologies and Applications "

Realization of Fuzzy Logic Controller in Microgrid for Mongolian Case

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Abstract[1]-This paper presents the development and simulation of photovoltaic (PV), wind turbine and battery energy storage system (BESS) based microgrid in a Mongolian case. Although many standalone solar and wind microgrids are installed in Mongolia, they are not operating at total capacity and reliably due to a lack of control and proper use. The microgrid system operates in autonomous mode to serve the loads. To effectively control the microgrid voltage and frequency and achieve smoother power flow control between the generation and consumption, voltage–frequency (V/F) control based on the fuzzy logic controller (FLC) is proposed. Even though there are sudden load variations in the system and fluctuations in PV output power, the microgrid voltage and frequency are effectively maintained within limits by the proposed FLC. A fuzzy logic controller is used for an off-grid operated Microgrid constituted by the solar system, wind system and battery. The PV, wind turbine and BESS-based microgrid system are simulated using Matlab/Simulink.

Keywords—autonomous Microgrid, distributed generation, photovoltaic, wind turbine, battery storage

I. INTRODUCTION

The increase in electrical energy demand in the current scenario makes the world turn towards using renewable energy sources. The best way to utilize renewable energy sources is through a microgrid. Microgrids have multiple distributed energy sources and energy storage elements nearer to the consumer [1].

The evolution of microgrids starts with the view that the power loss during the transmission can be significantly reduced, the maximum utilization of renewable energy sources can be achieved, reliable power to the consumers, pollution-free environment etc. The Microgrid is the collection of various renewable energy sources such as solar, wind turbine, fuel cell, energy storage elements and loads [2]. The microgrid operation may be considered the autonomous mode of operation, connected with the conventional grid or transition mode [3].

The best way to provide electricity in remote areas is to use solar and wind energy in areas not connected to the central region's power system. Mongolia produces 80-90 per cent of its energy from thermal power plants with fossil fuels such as coal, oil and diesel. Hydropower, solar and wind power generation account for only 3% of total energy [4]. The effective use of Microgrid is put down in the proper selection of the size and location of the distributed generation (DG) sources [5]. The MPPT-based fuzzy logic control for a standalone solar system has been proposed in [6]. For various weather conditions, the fuzzy controller results are compared with the perturbation and observation algorithm, and the results prove that the proposed algorithm gives a better tracking performance response. Even the fuzzy logic controller is used for an induction motor speed control [7]. A fuzzy-based control algorithm for analyzing the charging and discharging level of the battery used in hybrid wind and solar power systems for standalone applications has been implemented in [8].

Most localities in Mongolia are not connected to the regional power system and do not have sufficient daily electricity supply in rural areas. Residents of this region will be able to meet their electricity needs using an integrated solar/wind system. In Mongolia and worldwide, solar and wind power are used to generate electricity. Recently, interest in a hybrid system connected to a power grid-connected system has been increasing. Mongolia has solar/wind integrated microgrid systems with 70kW to 200kW. As seen from the table below, most installed microgrid systems do not operate at full capacity and sustainability due to a lack of proper use and control of microgrids. Information on the local Solar and Wind integrated power stations built in Microgrids is listed in Table 1.

Table 1. Information on the local Solar and Wind integrated Power Stations built in Microgrid

№	Location	Description (type, capacity)	Client and contractor company	Results and current situation
1	Bayankhongor Bayan-Under soum	Solar and wind- capacity of 150kW,	Client: National Center for Renewable Energy Contractor: Bayan Construction	Out of 12 wind turbines, 9 wind turbines did not work, and 2 solar panels were broken. It provides electricity for 14 hours a day.
2	Bayankhongor Bayantsagaan soum	Solar and wind- capacity of 150kW,	Client: National Center for Renewable Energy Contractor: Bayan Construction	Out of 12 wind turbines, 8 wind turbines did not work, and the solar power plant controller was broken.
3	Bayankhongor Shinejinst soum	Solar and wind- capacity of 150kW,	Client: National Center for Renewable Energy Contractor: Bayan Construction	Out of 12 wind turbines, 7 do not work, and the power plant operates normally and supplies the soum with electricity for 7 hours a day.
4	Gobi-Altai Altai soum	The solar power plant's capacity of 200kW	Client: Ministry of Energy Contractor: Kyocera (Tianjin) LLC, China	Working normally.
5	Gobi-Altai Bugat soum	The solar power plant's capacity of 60kW.	Client: National Center for Renewable Energy Contractor: “New Power” LLC	Since 2010, it has normally been operating and supplying the soum with electricity.
6	Gobi-Altai Tsogt soum	The solar power plant's capacity of 100kW	Client: Ministry of Energy, World Bank Contractor: Kyocera (Tianjin) LLC, China	It is powered 24 hours a day.
7	Gobi-Altai Tseel soum	Solar and wind- capacity of 150kW	Customer: National Center for Renewable Energy Contractor: “Khurd” LLC	The two wind turbines are fully operational, and the solar power plant is operating normally, but the batteries are poorly charged.
8	Dornogobi, Mandakh soum	The combined solar and wind power plant has a capacity of 200kW	Client: National Center for Renewable Energy Contractor: “Prestige Engineering” LLC	Since 2010, it has been supplied with electricity 24 hours a day.
9	Dornogobi , Khanatbulag soum	The combined wind and diesel station has a capacity of 150kW	Customer: National Center for Renewable Energy Contractor: “Mongol Alt” LLC	The XL10R has 15 10kW wind turbines and 240 batteries with automatic control inverter.
10	Dornod, Matad soum	The combined solar and wind power plant has a capacity of 120kW	Customer: National Center for Renewable Energy Contractor: “Bayan Construction” LLC	Of the 9 wind turbines, 6 were damaged.

II. MODELLING OF PV SOLAR-WIND SYSTEM

Hybrid Power System is designed to provide sustainable energy to consumers using solar/wind energy in remote areas. Combined systems are classified as follows.

1. Off-Grid system
2. On-Grid system

The microgrid system consists of PV panel, Wind Turbine and Battery. The general scheme is shown in Figure 1 below.

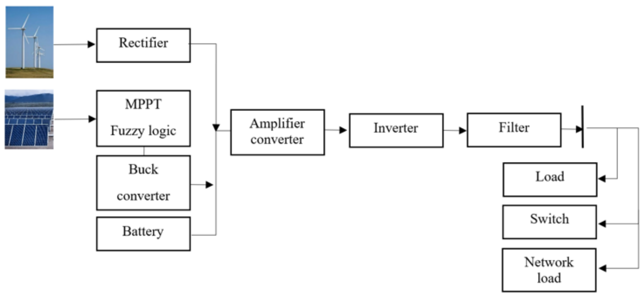

Figure 1. Simple schematic diagram of an integrated station

Figure 1 shows that the voltage value before entering the DC converter of the solar/wind integrated system, or at the PV output, depends on the wind turbine's parameters and wind speed, which varies significantly from the environment.

The PV module of a solar power plant is determined by the number of serial connections, the system voltage, and the number of parallel-connected currents. A wind farm converts kinetic energy into mechanical energy with the help of a generator to generate electrical power.

The power produced by the turbine is directly related to the wind speed, measured in cubic meters. This increases the motor's output power as the electromagnetic torque and circuit power increase as the load on the motor shaft increases.

However, when the motor's mechanical load increases sharply, the rotation of the armature on the shaft slows down, the value of the electromotive force decreases and the current is determined. In generator mode, the external mechanical power on the shaft is converted into active electrical energy by an alternating current in the network.

The simulation below (Andalay Solar) uses a KC210-1 module and a vertical three-blade turbine generator. The combined system's PV module has a 50kW cross-connection, the wind turbine has a 20kW, an inverter with a DC-DC (Buck) converter, an amplifier and an MRT (Fuzzy Logic) method to control it.

Many papers have proposed the fuzzy logic controller mostly for standalone applications. This paper presents a Fuzzy logic controller for the Grid-connected solar and wind system using a Fuzzy logic controller with battery backup controlled by a buck-boost converter.

III. FUZZY LOGIC CONTROLLER (FLC)

Fuzzy logic is popularly used nowadays for controlling various parameters in the system. In the Microgrid, FLC finds its application in controlling the peak point in the MPPT. Fuzzy logic includes three basic function blocks Fuzzification block, Inference Engine and Defuzzification block. Here the voltage and the current from the solar panel determine the power.

The MPPT control is used for finding the change in the duty ratio of the DC-DC converter by considering the slope of the P-I characteristics of the solar cell. The slope is considered as the error E, and the change in the error (CE) is also taken as input variables to the Inference engine [9]. The input variables are converted to the fuzzy variables as NB (Negative Big), (NS) Negative Small, (Z) Zero, (PS) Positive Small, PB (Positive Big) using the fuzzy subset.

The fuzzy rules are created and given in Table 1. The operating point at which the power output is maximum can be adjusted by adjusting the duty ratio. The proposed fuzzy rules provide the maximum operating point and the constant voltage output at the grid side.

Table 2. Fuzzy Control rules

ΔD	E					
	NB	NB	NB	NB	NS	NS
CE	NS	NB	NB	NS	NS	NS
	Z	NB	NS	NB	PS	PB
	PS	PS	PS	PS	PB	PB
	PB	PB	PB	PB	PS	PS

IV. SIMULATION RESULTS

The simulation circuit for the grid-connected micro-grid in MATLAB/Simulink. The constant DC voltage from the solar panel is synchronized with the battery voltage, and it is given to the inverter. The inverter converts the fixed DC into AC supply for supply to the grid. The simulation is carried out for 1000W/m^2 and 800W/m^2 irradiation levels in offline conditions. After running the simulation, the results and the Fuzzy controller can maintain the constant voltage at the grid level.

In this paper, a 50kW - Microgrid Solar-Wind integrated power system was installed using the MPPT (Fuzzy Logic method). Figure 2 shows the simulation circuit for the Maximum power point tracking subsystem used in the controller. The Fuzzy Inference System (FIS) takes the input and applies the fuzzy rules to make the fuzzy outputs.

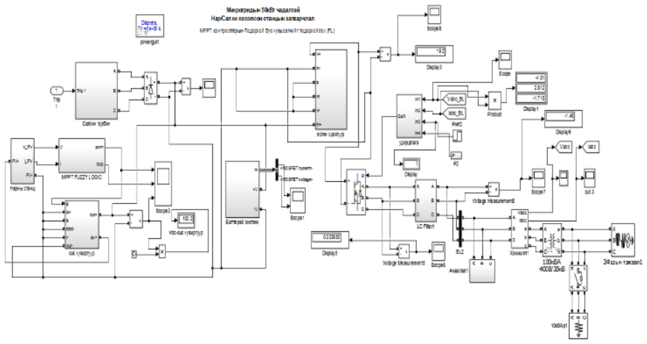

Figure 2. Modelling of a 50kW Solar/Wind integrated power system to determine the maximum power FL.

The simulation results show that the time and voltage of the solar/wind station are 2 seconds, the solar radiation intensity is 1000W/m^2, the wind speed is 14 m/sec, and the temperature is 25 °C.

Figure 3 shows the time dependence of the inverter output voltage value and the output voltage value after the output filter.

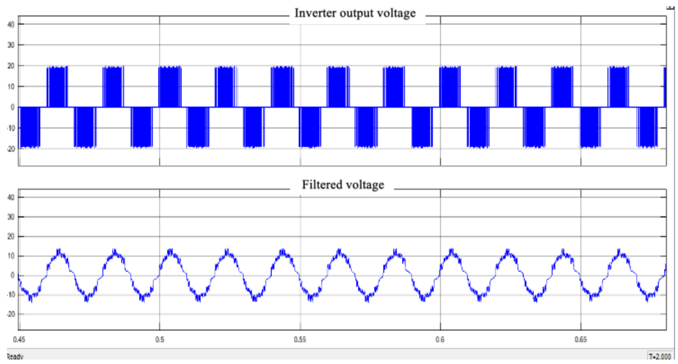

Figure 3. The time dependence of the inverter output voltage value and the value of the output voltage after the output filter

a) Inverter output voltage b) Voltage after the filter.

Depending on the wind angle speed and the turbine output power, AC is fed to the amplifier using a rectifier.

Depending on solar radiation and temperature, the output power is fed to the Buck converter via the Fuzzy logic, and when the voltage pulse from the control system to the transistor is dissipated, the power transistor VT is turned off, and the total current of the electromotive force goes to the inverter.

Figure 4 shows Solar/Wind/Battery Output Voltage (Boost Converter) The time dependence of the output voltage after the boost converter.

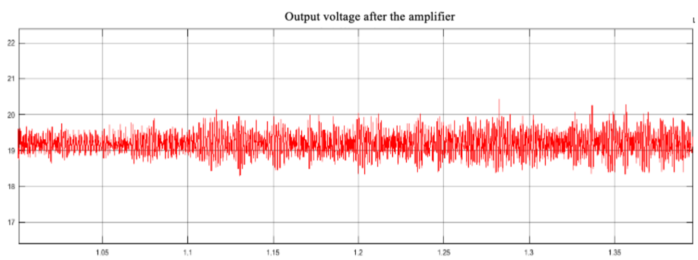

Figure 4. Solar / Wind / Battery output voltage, (Boost converter). Time dependence of the output voltage after the amplifier.

Figure 5 shows the relationship between the current and voltage of the inverter controller over time.

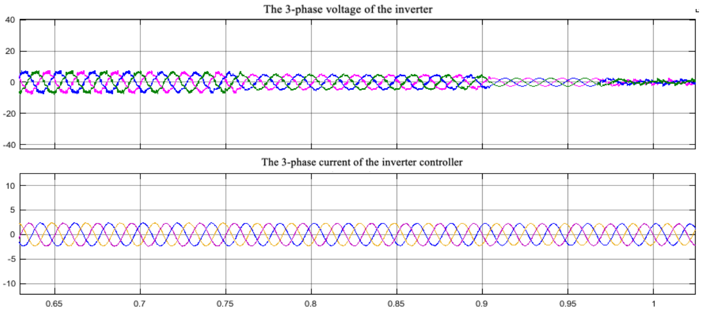

Figure 5. Inverter controller current and voltage dependence over time. a) 3-phase voltage of the inverter controller b) 3-phase current.

Figure 6 shows the time dependence of the output power of the FL of the solar power system's MPPT and the output voltage after the Buck converter.

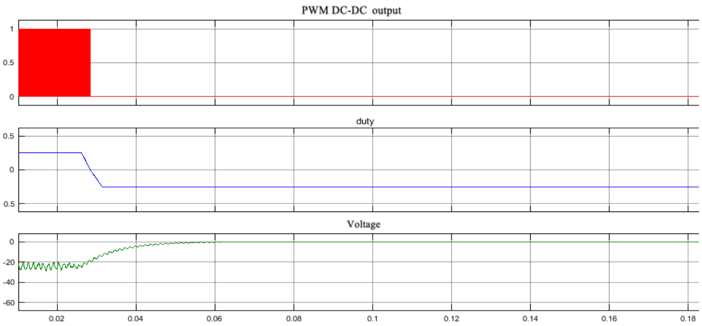

Figure 6. The output power of the FL of the solar power system's MPPT and the output voltage after the Buck converter. a) PWM DC-DC output b) Duty c) Voltage

Figure 7 shows the dependence of the load current and voltage on time.

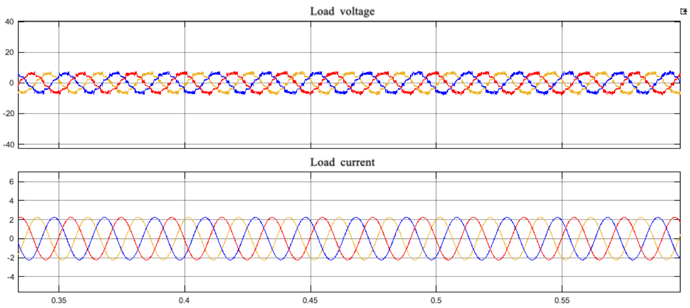

Figure 7. Load current and voltage dependence over time. a) Load voltage b) Load current.

Figure 8 shows the time-dependent output voltage of the solar PV module and MPPT of the PV module, and current and voltage depending on the circuit time of the Buck converter.

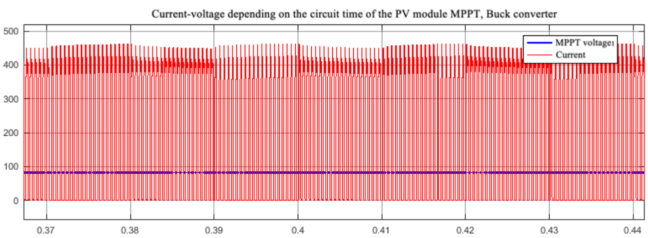

Figure 8. Current-voltage depending on the circuit time of the PV module MPPT, Buck converter.

Figure 9 shows the voltage dependence of a DC rechargeable battery for 2 seconds.

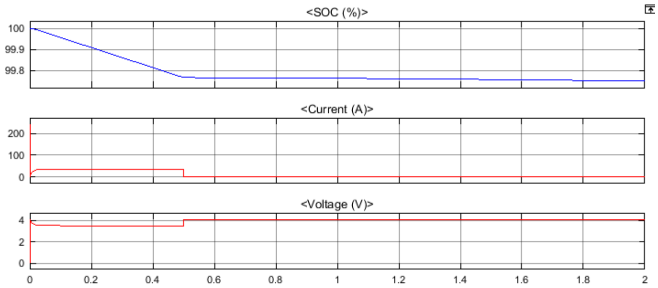

Figure 9. Dependence of current and voltage on a DC rechargeable battery for 2 seconds.

The following Figure 10 shows a comparison of Fuzzy logical results.

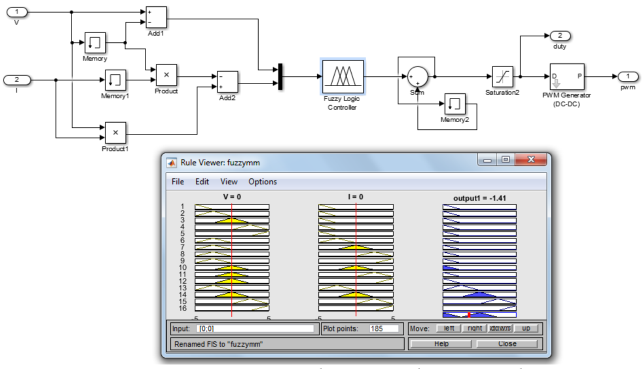

Figure 10. Fuzzy logic simulation results

Figure 11 shows the maximum harmonic concentration of the inverter output voltage, the start time of the analysed cycle is 0.02s, and two complete phases.

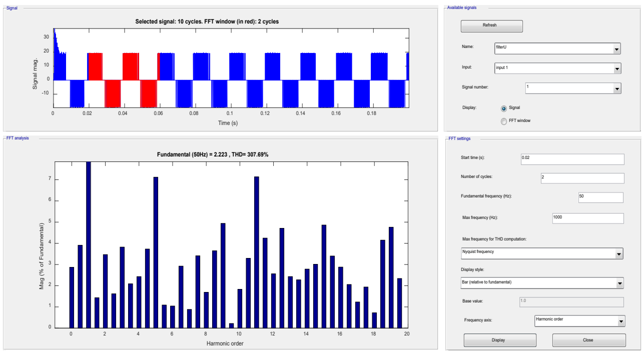

Figure 11. The maximum harmonic concentration of the inverter output voltage, start time of the analysed cycle 0.02s, and two complete phases.

V. CONCLUSION

This paper proposes an efficient power management system that uses the Fuzzy logic controller (FLC) to adjust the controller's duty ratio in the MPPT technique.

This paper, a model of a 50kW solar-wind integrated power system using the MPPT Fuzzy logic method was performed. Simulation time was 2 seconds, solar radiation intensity was 1000W/m^2, the wind speed was 14m/sec, temperature was 25°C, and instantaneous solar/wind station DC and AC circuit parameters were analysed. The circuit of the Buck converter, which maintains a constant voltage value, is stabilized from the first 0.2 seconds of the simulation, which does not depend on the current solar intensity, and is capable of producing low-voltage power under the control MPPT. Using the Fuzzy Logic method of MPPT control of an integrated solar and wind system, the program calculates the uncertain input variable based on a comparison of the recharging percentage and capacity of the battery. It gives the maximum voltage to the output. This means that the voltage after the inverter and after the filter of the MPPT is stable.

Due to Mongolia's vast territory and small population, the rural population must receive a stable and uninterrupted energy supply, and the energy system has a problem of insufficient capacity. Although many standalone solar and wind microgrids are installed in Mongolia, they are not operating at full capacity and reliably due to a lack of control and proper use. Recently, medium and large-scale solar and wind power plants have been installed and operated with the grid.

Mathematical modelling of the Integrated Renewable Energy System can improve its reliability, management and protection, and impact on the energy system and equipment safety. Furthermore, it has the advantage of improving technological capabilities. The benefit of increasing the stability and efficiency of the system is that the microgrid control and coordination operating in parallel with the network are well adapted to the characteristics of the power system. Designing and improving the microgrid control and management system by simulating and improving it based on real cases is the key to ensuring the stable and efficient operation of the Mongolian Microgrid and developing a smart grid. The most widely used protections in Mongolia are SEL3351, 751a, and 351, equipped with relay protection equipment to monitor and control the combined station through Scada. Further research will model the management and operation of medium and large solar and wind power plants operating parallel with the system.

VI. Referenc

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