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Fault control of microgrid system: a case study the College of Civil Aviation and Meteorology

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ABSTRACT
In this paper, the College of Civil Aviation and Meteorology microgrid system is introduced and fault control of microgrid is analyzed. The microgrid system of the College campus consists of solar PV panels, an energy storage unit, a diesel generator, and critical and non-critical loads. Fault control has been implemented in the microgrid system to manage power in the system effectively. The system disconnects the microgrid effectively from the main grid within a microsecond after fault conditions. The distributed energy sources have supplied the energy to load-based load profile settings. Simulation of microgrids in both grid-connected and isolated operation modes is conducted on MATLAB/Simulink. From the simulation results, the developed control mechanisms provide stable operation in the microgrid system.

Keywords: Solar PV panels, Energy storage unit**,** Diesel generator, Microgrid.

I. INTRODUCTION

In the last decades, the energy demand has grown exponentially worldwide. The development trends of power systems in the world require not only to increase electricity production in large power plants but also increasing the share of distributed generation (DG) based on renewable energy sources. Photovoltaic, fuel cells, wind power, microturbines, gas turbines and internal combustion engines are examples of distributed energy resources. Distributed energy resources (DER) have advantages over centralized powergeneration. These advantages include the system stability improvement, the reducing transmission and distribution overload, power losses reduction, voltage profile improvement, pollutant emission reduction [1-3]. The reliability and power quality of electrical energy should be provided to consumers such as hospitals, multi-storage buildings, information centers, university campuses, etc. [4-6].

In general, the electricity generation from renewable energy sources is most suited method than convention energy generations. But it has some disadvantages such it is not stable due to climate change, inefficient and initial cost for installation is high. In other hand, diesel power generator used during emergency situation and peak hours and normally used for standby power to supply the peak loads and it used only in isolated area. Even though, it has some advantages such as reliable, flexible, low cost, high efficiency. Advantages of both renewable energy and diesel. generations are included in microgrid[7-9] One of main reason of microgrid inter connection to power systems is to share reserves in emergency conditions (for example, loss power in maingrid) for lowing the chance of load shedding and enhancing the overall system reliability. The following advantages of MG are noted in literature [10-12]:

- The ability of MG, during a utility grid disturbance, to separate and isolate itself from the utility seamlessly with little or no disruption to the loads within the MG;
- In peak load periods it prevents utility grid failure by reducing the load on the grid;
- Significant environmental benefits made possible by the use of low or zero emission generators;
- The use of both electricity and heat permitted by the close proximity of the generator to the user, thereby increasing the overall energy efficiency;
- MGcanacttomitigatetheelectricitycoststoitsuser sbygeneratingsomeorallofitselectricity needs;
- Enhancing the quality of power which is delivered to sensitive loads.

Moreover, the combination of renewable energy with distributed storage system and diesel power generator in MG is most promising solutions to assurance for continuity of power generation with moderate expenditures on equipment. Apart from these advantages of MG, there are some issues in the MG system. First one is the intermittent and fluctuant availability of RESs as a result of which there are disturbances in the system and the power quality is deteriorated. Another problem is planning, designing,and available technology at low cost to install in the MG system. Also, the precise measuring andcontrolling are required to maintain stable operation due to use of power electronic devices in the MG [13- 15].

This paper proposes a microgrid system with power flow control in allDER along with fault control.The proposed microgrid consists of solar PV array - battery storage system with local load and diesel generator with local load. The prime objective of this work is to design and develop the control system of MG to ensure the power balance between DERs and load along withcontinues energy supply during the failures.

II. METHODOLOGY

The integration of DERs and energy storage devices to existing power distribution network makes problems such as to provide the operating reliability and efficiency of electricity system. Therefore, precise design and modelling microgrid system with control ensure the stability of power system.

Firstly, the initial problem of the College of Civil Aviation and Meteorology (CAM) electricity has been evaluated. The College is one of the great electricity consumers in the province with 435877 kW•h monthly average electricity consumption for 2018.

There are problems such as increasing utility bills, indirect carbon emissions, and also cost of maintaining a complex distribution infrastructure with trying to provide electricity a large university community. College of Civil Aviation and Meteorology governance is intended to reduce electricity consumption and attendant costs by integrating solar photovoltaic (PV) panels into the utility grid of the College campus. Nowadays, PV panels are installed in five of the eight main educational buildings on the College campus. Therefore, MG planning, modelling and simulation are performed in this work on the example of the Civil Aviation Faculty at the College of Civil Aviation and Meteorology.

Microgrid of the College of Civil Aviation and Meteorology MG has the following main components:
1. Diesel generator;
2. PV-system;
3. Energy storage system (battery storage unit).

4. Critical and non-critical loads.

Civil Aviation Campus is the central campus of the College of Civil Aviation and Meteorology with a building area of 1.5 million m^2. The electric power of the College of Civil Aviation and Meteorology campus is supplied by power supply substation.

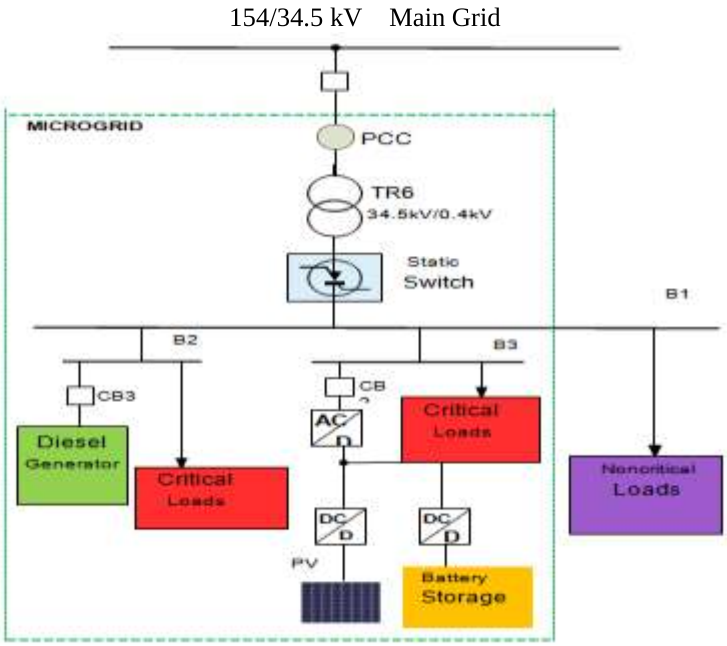

Figure 1.Single line diagram of College of Civil Aviation and Meteorology Microgrid.

III. RESULTS AND DISCUSSION

The College of Civil Aviation and Meteorology Microgrid system has been created on MATLAB/Simulink environment. Technical parameters of rating of the studied system is given in the Table 1. The simulation is executed in the Windows 10 64 bit OS, a dual-core 1.7 GHz Intel Core i5 processor. The Simulink model of the overall College of Civil Aviation and Meteorology microgrid is shown in the Figure 2.

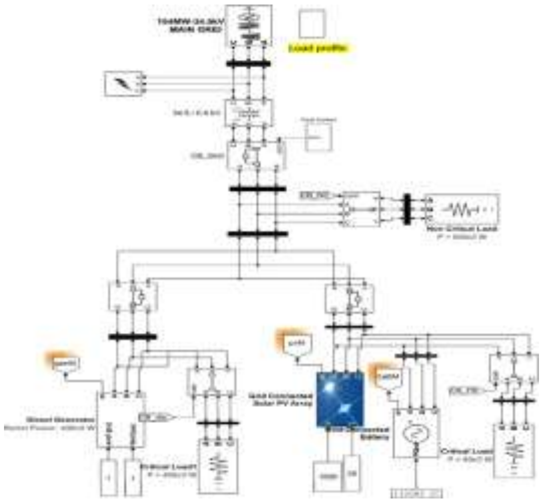

Figure 2. Simulink model of College of Civil Aviation and Meteorology MG system with fault and power flow control.

Table1. Specificationof College of Civil Aviation and Meteorology Microgrid

	Grid	Solar PV	Battery	Diesel Generator	Transformer	Load
Power	154 MW	41 kW	41 kW	440 kW	154 MVA	Critical load1– 400 kW at diesel generator
Voltage	34.5kV	400 V	480 V	400 V	34.5 kV/0.4 kV	Critical load 2 – 40 kW at solar battery inverter
Frequency	50 Hz	50 Hz Inverter frequency	50 Hz Inverter frequenc y	50 Hz	50 Hz	Non-critical load – 500 kW at grid bus
Capacity			500Ah			

The Simulink model of the fault control system is shown in Figure 4. In this Simulink model, root mean square (RMS) value of the fault lines are compared with rated value. If the actual voltage is less than the rated value, trip signal is sent to corresponding circuit breaker to isolate from the remaining healthy system.

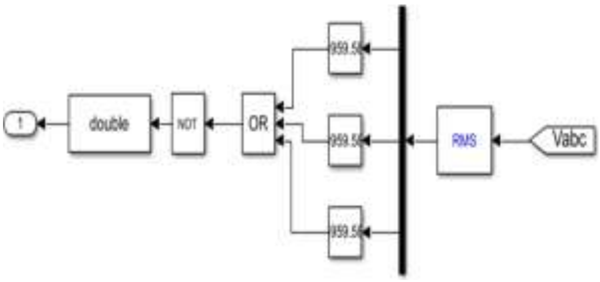

Figure 3. Simulink model of the fault control system.

The load profile settings for open and close conditions of the critical and non-critical loads circuit breakers are demonstrated in Figure 4. We can see how the load profile results change when circuit breakers of critical load 1 (supplied by diesel generator), critical load 2 (supplied by PV-battery-inverter system) and non-critical load disconnected and connected from power sources. While the circuit breakers of all load are connected in 0 – 2 sec. interval the load profile is 980 kW; when the circuit breaker of critical load 1 is connected, but the circuit breakers of critical load 2 and non-critical load are disconnected from 2 sec. to2.5 sec. the load profile is 400 kW; in 2.5 – 3 sec. interval when the circuit breaker of critical load 2 is connected, but the circuit breakers of critical load 1 and non-critical load are disconnected the load is 80 kW; while the circuit breaker of non-critical load is connected, but the circuit breakers of critical load 1 and critical load 2 are disconnected from 3 sec. to 3.5 sec., the load is 500 kW; and in 3.5 – 4 sec. interval the load is again 980 kW.

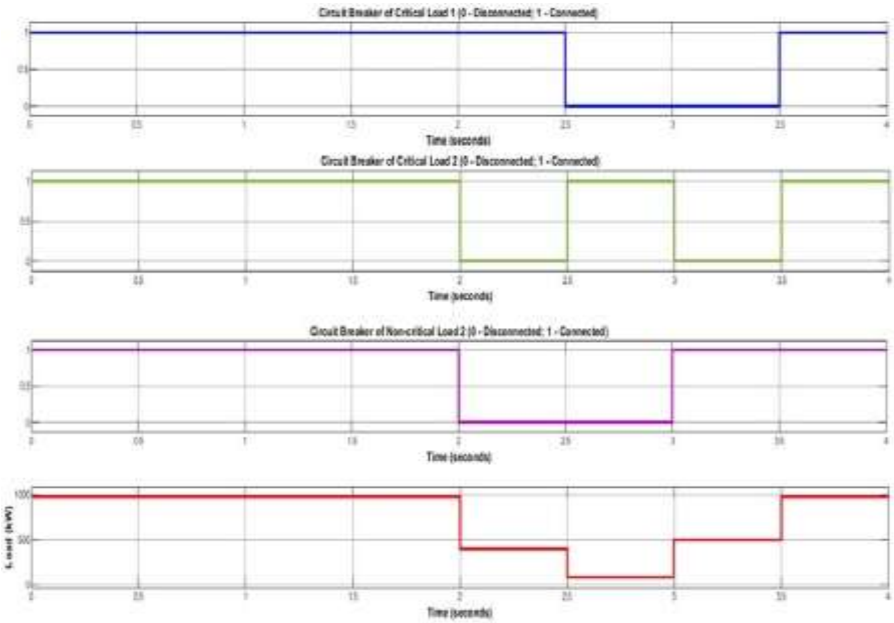

Figure4. Load profile and circuit breaker signal for different loads.

In order to verify the effectiveness of the system, the following test cases have been taken for analyses:

- Three phase faults at grid line conditions;
- Optimal load sharing conditions.

The active power characteristics of grid, solar PV, battery and diesel generator are illustrated in Figure 5. Also, island mode and grid connected mode of the Microgrid system is presented in the Table 2 and this table provide the sharing of the active power of the grid and distributed energy sources such as PV, battery and diesel generator.

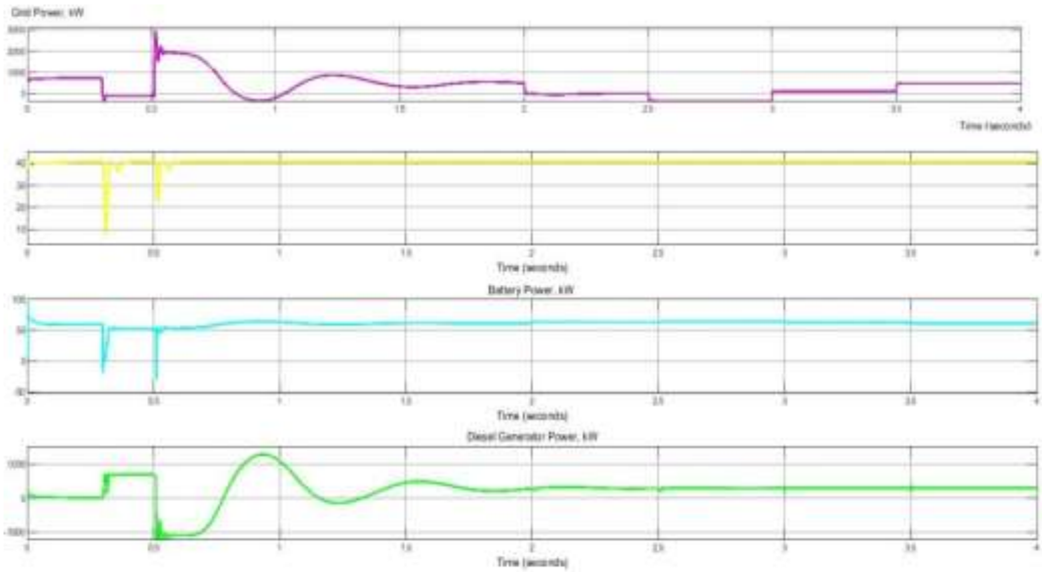

Figure5. Power characteristics of grid, solar PV, battery and diesel generator

Table 2. Active power sharing of the Microgrid system in grid connected and island modes.

Time (sec.)	0 - 0.3s	0.3 - 0.5 s	0.5-2s	2 - 2.5s	2.5 – 3s	3-3.5s	3.5–4s
				Load	Profile	(kW)	
	980	980	980	400 Grid -110	80	500	980
Power	G	G	G		G	G	G
Source	901	0	470		-430	-10	470
(kW)	PV-B		PV-B		PV-B		PV-B
	D		D		D		D
Operation	G	I	G	G	G	G	G
mode	C		C	C	C	C	C

The fault simulation status and RMS voltage of the system are shown in Figure 6. The fault is occurred at 0.3 sec in main grid and resets at 0.5 sec. During the fault RMS voltage is less than rated value and due to that open command is given to corresponding circuit breaker to isolate the system.

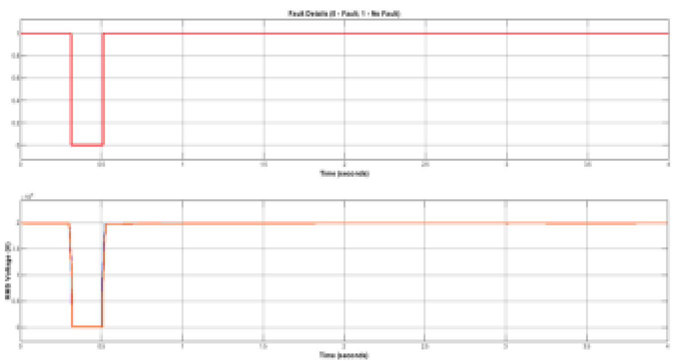

Figure 6. Fault details and fault voltage at area.

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The critical and non-critical load profiles while the fault in main grid are shown in Figure7.

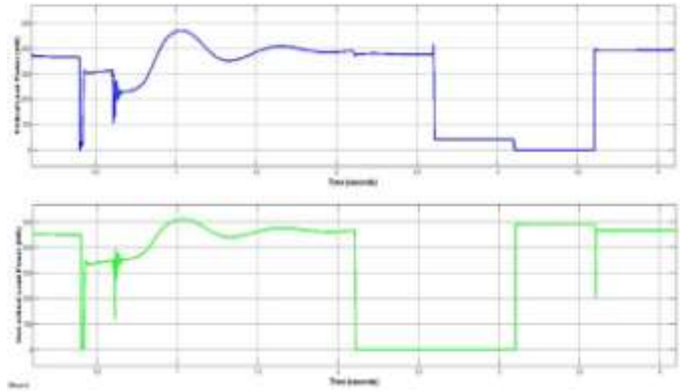

Figure7. Criticalandnon-criticalloadprofileswhilethefault.

Figure8andFigure9 show the variation of the voltage and current at PV battery bus, diesel generator bus, the voltage and current of the loads at diesel generator bus and PV-battery bus, respectively. Variation ofthe voltage and currentfollow the load profile settings.The system effective work in both cases such fault control case and optimal load sharing case.

Figure 8 shows the voltage and current of the PV-battery bus. The load is maintained of 230 V at the following intervals:0–0.3sec.; 0.5sec.–2sec.; 2.5sec.–3sec.; 3.5sec.–4sec. while faults occur. The voltage is slightly reduced to 230V. Load is disconnected during 2sec. to 2.5sec. and 3sec. to 3.5sec. based on load profile settings. Thecurrent of the system is varying according to load and fault conditions.

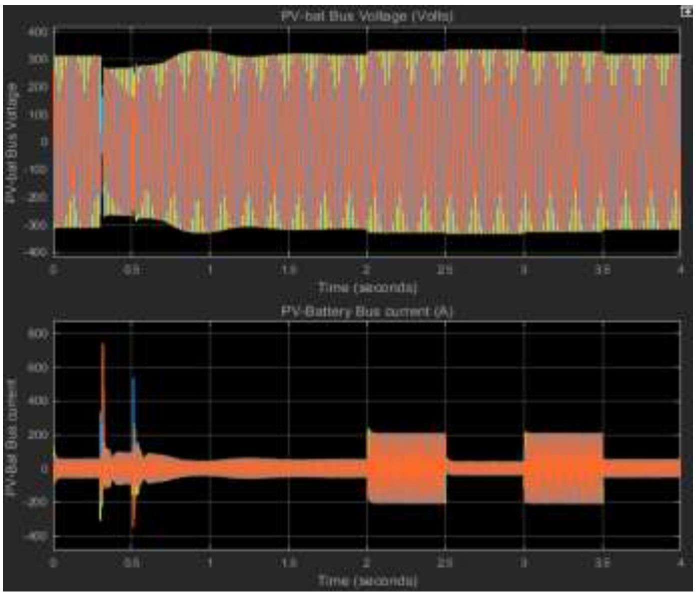

Figure8.PV-battery bus voltage and current.

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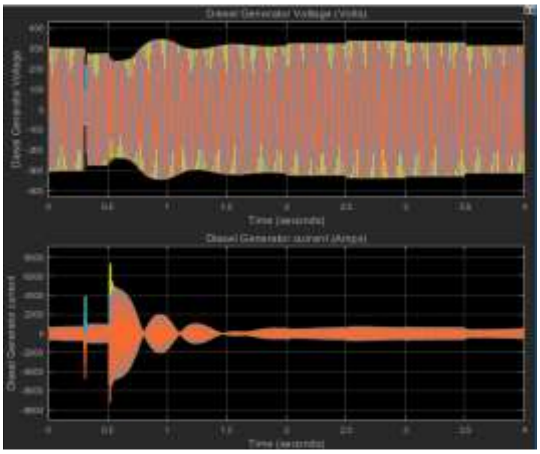

Figure9. Voltage and current of diesel generator.

The voltage and current of diesel generator are showninFigure9. Load is maintainedof230 V at intervals 0 – 0.3 sec. and 0.5 sec. – 4 sec. during fault conditions, voltage is slightly reduced to 230 V. The load is disconnected during 2.5– 3.5 sec. based on load profile settings. The current of the system isvarying according to load and fault conditions.

The frequency analysis of the microgrid system is shown in Figure 10. From 0 to 0.3 sec, the frequency of the system is maintained of 50 Hz. When fault occur during 0.3 to 0.5 sec., the frequency is reduced to 48 Hz. After fault cleared, the frequency of the system is restored to 50 Hz after 2 seconds. After fault it takes 1.7secondstorestoretoratedfrequency.

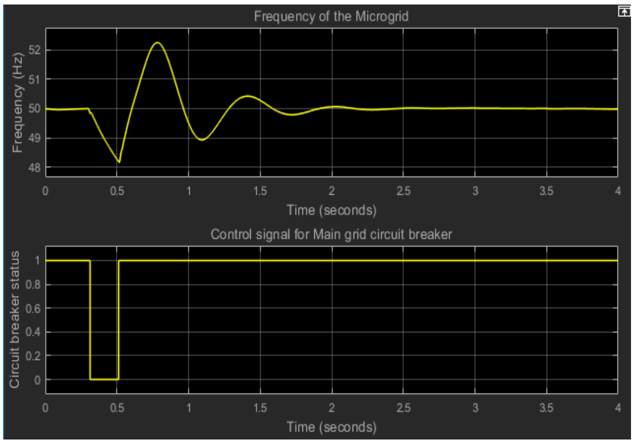

Figure10. Frequencyresponseduringgridandislandmode

IV. CONCLUSIONS

The microgrid architecture for the College of Civil Aviation and Meteorology was introduced and analyzed in this paper. This microgrid includes a diesel generator and solar PV systems with battery storage. Simulation of microgrids in both grid-connected and isolated operation modes has been implemented on MATLAB/Simulink. Fault control has been implemented in the microgrid system to effectively manage the power in the system. The system is effectively disconnecting the microgrid from the main grid within a microsecond after fault conditions. The distributed energy sources have been supplying the energy to load-based load profile settings. In addition, a microgrid control strategy in grid-connected mode and isolated grid mode was proposed.

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