Rule-Base Current Control for Microgrid Energy Management System

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***Abstract*—Rule-base current control for Microgrid Energy Management System (EMS) is an idea to managing different micro sources by using rule-base to allow each resource to participate in the Microgrid in prober time when needed. These resources are Photovoltaic (PV), wind turbine (WT), fuel cell (FC), and diesel generator and battery storage. Every source waits for a control signal from the rule-base controller to connect or disconnect from the Microgrid based on pre-prepared rule bases. Since this Microgrid needs a load, a real load data of 2MW has been collected and involved in the system. This load has been built by Matlab Simlink for 24 hours, wherein each hour was represented by 0.1Sec in the simulation and the power factor was 0.85. The controller has been tested in real residential and industrial load data taken from TNB in Selangor, Malaysia. Represented as Microgrid control signal for each source, rms current signal, and sinwave current signal, the results expressed controller's behavior when the current decreases and increases.**

***Index Terms*—Current Control; Energy Management System; Microgrid; Rule-Base.**

I. INTRODUCTION

The idea of changing the conventional electricity grid and the transmission line cost and losses allows more flexible incentives based on demand response programs. Reliability aspects have been more challenging in remotely operated independent Microgrid Networks [1]. Microgrids are localized grids that can disconnect from the traditional grid to operate autonomously and help mitigate grid disturbances to strengthen grid resilience [2]. Microgrids contain several generators, whose sizes may range from several tens of kilowatts to a few megawatts [3]. However, they are similar to those of utility scale power distribution grids, which generate, transmit and regulate electricity to the consumers locally. These generators require a management calls Energy Management System (EMS). EMS is a way of organizing different resources simultaneously. This paper focuses on developing current controller strategy to make decisions which and when each sources can participate [4]. Five different sources have been used in this study: Photovoltaic (PV), wind turbine (WT), fuel cell (FC), diesel generator and battery storage [5]. All of these generators are connected to an area load and connected by wireless telecommunications system as shown in Figure 1. Each source is on a standby mode and ready to participate when the controller requests anyone of them from the central control unit in EMS. Rule-base rules has been evaluated and tested several times to ensure every source can contribute when it is needed by focusing on the Microgrid output current [6] [7]. When the current decreases, the system will switch off some sources and vice versa when the current increases. The entry or exit of any of the resources will be based on the three options, namely the wind speed, sun irradiations and power demand. The rule-base is set to be friendly with the environment by using sustainable and renewable resources as a priority: Only if it is not available, then it will use the other ordinary resources.

This paper tackles the system modeling, including the rule-base main work and real energy demand, followed by the results and discussion, and finally, the conclusion of the paper.

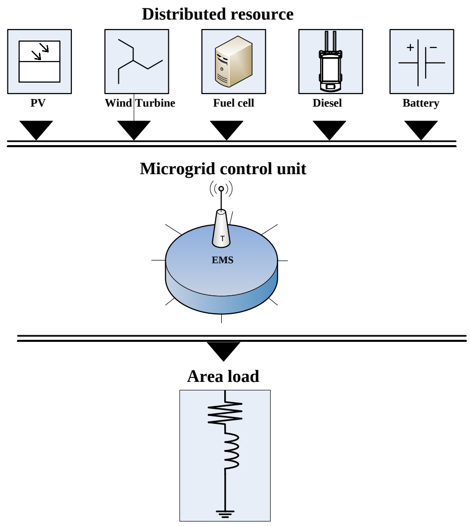

Figure 1: Five micro sources act as one Microgrid managed by EMS.

II. SYSTEM MODELING

The system modeling is represented by a block diagram prepared by Matlab Simulink. The system includes a Microgrid with five sources supplying power to local area load, as shown in Figure 2. All Microgrid sources in this system were controlled by a central controller that relies on rule-base current control to allow one or more than one source to participate at the same time. The Microgrid has five-source generations with the power capacity up to 2 MW. The Microgrid's current is the key factor for the controller. The controller makes a decision based on a set of rule-base considering that the decision depends on the weather conditions and the values observed by the controller every time. The Matlab function was used as a medium of writing the code for the rule-base. The controller input is only one signal, which is the current, and there are five outputs in which each output gives a control signal for each source of the Microgrid. Load has been established as resistive and indicative load in series: For each hour, the load changed based on the actual real demand as stated on Table 1, and the power factor for the load was 0.85. Figure 3 shows the real curve demand of residential load and Figure 4 shows the real curve demand of industrial load. Both of these data have been taken from TNB in Selangor area for 24 hours.

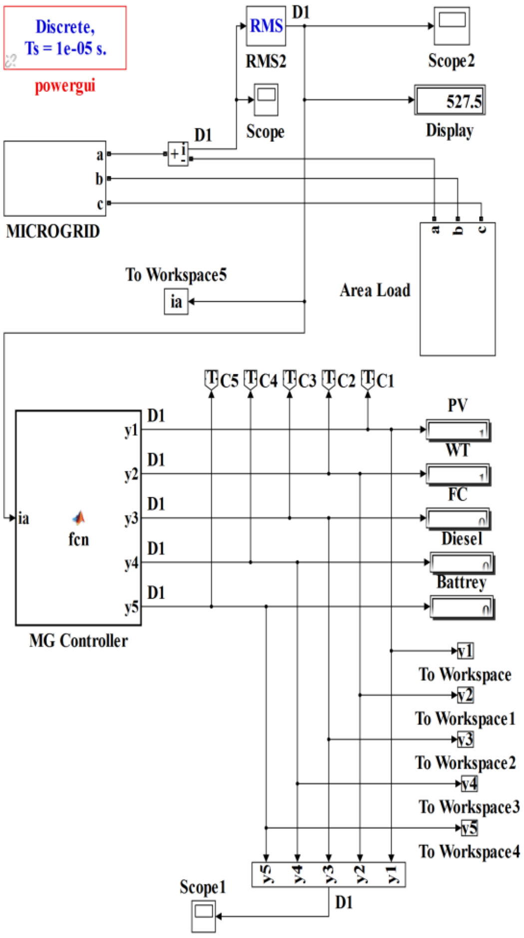

Figure 2: Matlab Simulink block diagram layout for Microgrid controller connection.

Table 1
Real power demand for 24 hours for indusial and residential load in area in Selangor, Malaysia

Time	Industrial Load		Residential Load	
	Demand/KW	QL/KVAR	Demand/KW	QL/KVAR
1	734.8487	454.2849	1950	1205.494
2	693.2816	428.588	1938.39685	1198.321
3	662.6661	409.6614	1938.51125	1198.391
4	641.6127	396.6462	1931.44835	1194.025
5	641.6127	390.6353	1882.70225	1163.89
6	625.846	386.8992	1875.5269	1159.454
7	646.8613	399.8909	1847.5054	1142.131
8	705.1656	435.9347	1833.3874	1133.404
9	773.734	478.3238	1160.8948	717.6674
10	843.5857	521.5063	822.5243	508.4861
11	908.431	561.5938	731.6088	452.282
12	944.1694	583.6874	650.0806	401.8811
13	972.3348	601.0993	585.8099	362.1488
14	994.9059	615.0528	730.7378	451.7435
15	996.1526	615.8235	624.0351	385.7797
16	1000	618.2019	578.20295	357.4462
17	992.2777	613.428	536.51845	331.6767
18	985.8662	609.4644	568.7188	351.5831
19	961.3086	594.2828	561.67345	347.2276
20	971.8228	600.7828	585.55575	361.9917
21	946.2568	584.9778	1198.8938	741.1585
22	906.3829	560.3277	1568.0093	969.3464
23	824.8083	509.8981	1633.0093	1009.53
24	774.4529	478.7683	1946.4328	1203.289

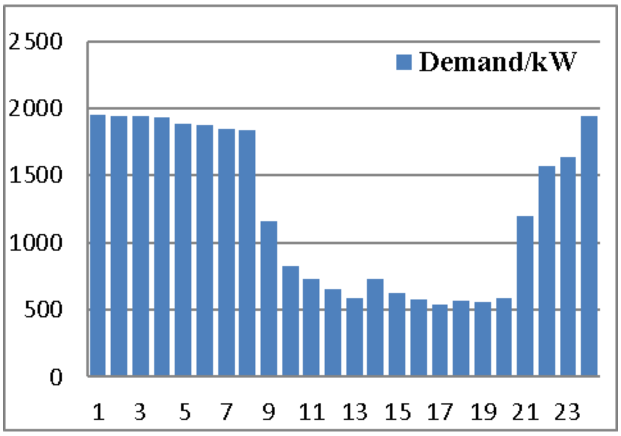

Figure 3: Real residential load curve demand in Selangor area for 24 hours.

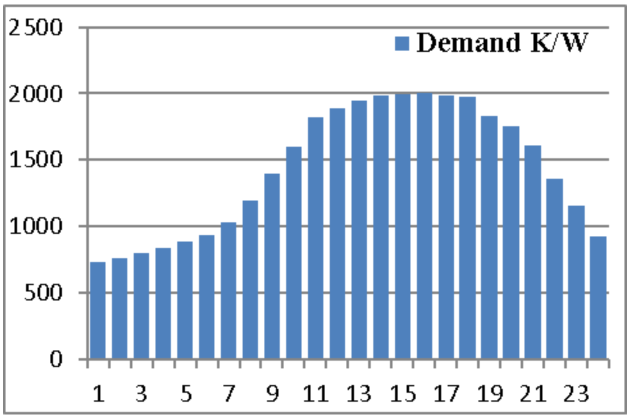

Figure 4: Real industrial load curve demand in Selangor area for 24 hours

Rule-Base Methodology

The methodology of the rule-base current controller works by relying on the demand needed by the load, which is translated to the controller as an amount of current drawn by the load. The flow chart in Figure 5 explains how the current controller works. It is as simple as when the current ic is more than or equal to the maximum current imax for all of the available resources in the Microgrid will participate. For example, when the current becomes less than imax, it will be any other amount between imax and minimum current imin, which are ix ix1, ix2….ix5. Each of this phase will turn on the number of micro source depending on the time and the availabilities of the resources, for example during night time, only the Wind turbine, Diesel generator, Fuel cell or battery can be utilized, but not the photovoltaic. When there is no wind blowing the wind turbine it will be excluded from the controller.

III. Results And Discussion

Generally, the demand of current in residential areas is higher during the night than the day just because all lights and air conditioning and other device are used. However, during the day time, most of residential areas will be almost empty with residents. Figure 6 shows the Microgrid current for a particular phase as it is supplying the current to a residential load. The increase or decrease of the current is subjected to the demand of the load: When the load is more, the current increases, and when the load is less, the current decreases. It is a proportional vice versa reponse. The current value was approximately at 1740 A, when at 12:00 AM and it decreased gradually until at 8:00 AM. Then, it decreased suddenly to approximately 1230 A after 8:00 AM followed by approximately 760 A and 550 A at 9:00 AM and 10:00 AM, respectively. The same change in the current signal is also shown in Figure 7, which shows the Sinwave signal for phase a of the Microgrid current feeding the residential load. Figure 8 shows the Control Signal for each source contributed in the Microgrid, when it was connected to the residential load. It showed that PV and WT were always connected because they are suitable resources and the other resources were disconnected and reconnected again to the Microgrid due to the load demand needed.

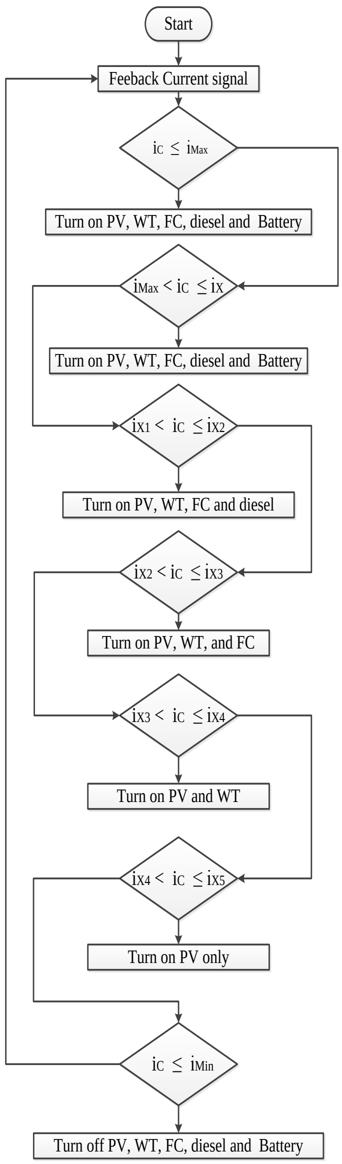

Figure 5: Rule-base current controller flow chart

Industrial load is normally high during the day since all the industries production lines are in operation and all the employees and workers are on their jobs. In Figure 9, the Microgrid current of phase a is feeding the area of industrial load. The signal of the current showed an increase of the power load demand. Figure 9 shows the current increased steadily from 8:00AM until 12:30 PM from approximately 1270 A to 1780 A. The current kept almost at the same value until 6:00PM and then it decreased steadily until it reached approximately 1090 A at 12:00 AM. Figure 10 shows the current Sinwave of phase for Microgrid in the case of theindustrial load. It shows the current increased from approximately 1100 A to 1780 A and decreased steadily. Figure 11 shows the Control Signals for every source contributed in the Microgrid when it was connected to the industrial load. It shows that more sources were contributing in comparison to the residential load, for example the PV, WT, FC and diesel were always contributing, while the storage battery contributed during rush hours only.

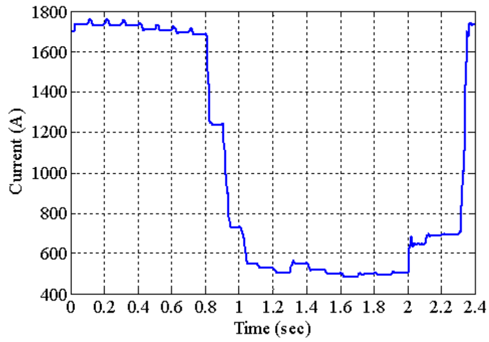

Figure 6: Microgrid current for phase a feeding the residential load

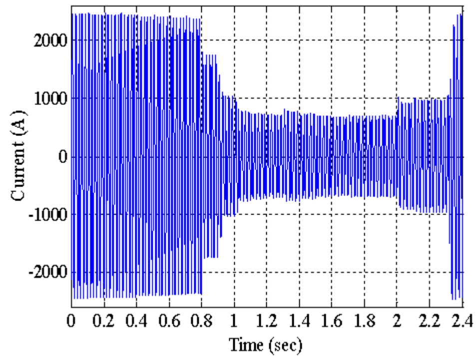

Figure 7: Sinwave signal of phase a total Microgrid current feeding the residential load

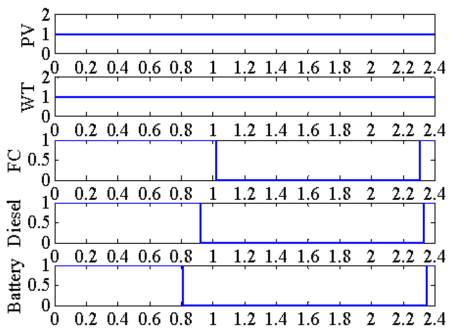

Figure 8: Control Signals for five sources contributed in the Microgrid when connected to residential load

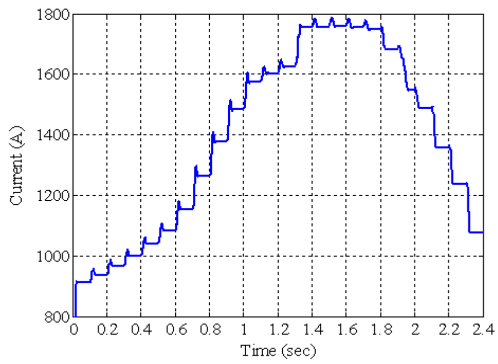

Figure 9: Total Microgrid rms current of phase a feeding the industrial load

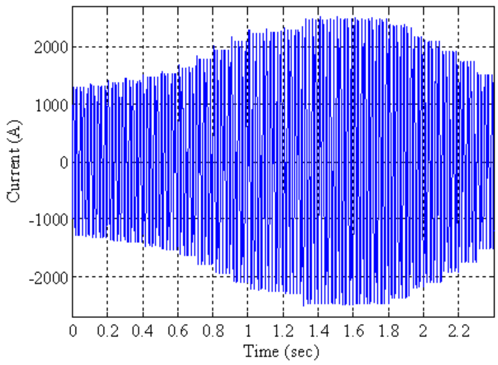

Figure 10: Sinwave signal of phase a total Microgrid current feeding the industrial load

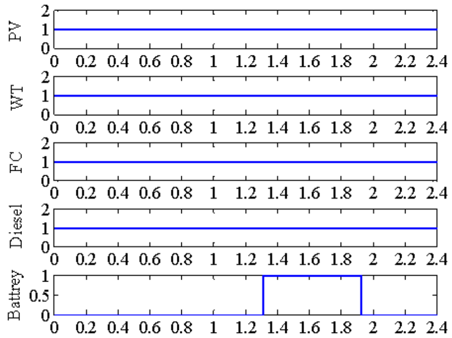

Figure 11: Control Signals for five sources contributed in the Microgrid when connected to industrial load

All of the results show a powerful effect of the rule-base strategies over the Microgrid, either when it was connected and fed to residential load area or when it was connected to the industrial load area. These rules have been tested several times with different loads conditions, and the outcomes were pretty good after adjusting the rule-base to suit the Microgrid and they gave a great effect.

IV. Conclusion

The nature of managing a Microgrid with different size of generator is a big challenge for any controller. In this study, Rule-base current controller has been utilized to manage a Microgrid of five generators with different fuel and different size. The rule-base has been prepared and adjusted to make it suitable for different loading conditions. Real-life data have been collected for one day from both the residential and industrial from TNB in Selangor area. The controller has been tested with non- industrial and industrial load. The results showed a great response in each hour the load changes. This controller can be more robust if it includes the irradiation and wind speed.

Acknowledgment

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