VANADIUM REDOX FLOW BATTERY AS AN ENERGY STORAGE SYSTEM FOR HYBRID MICROGRID APPLICATION

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ABSTRACT

Upon the advancing in renewable energy technologies, the interest in utilizing the resources has become in demanded overtime. With the rising trends of the renewable energy utility installed over the past years, the concept of exploiting the renewable energy resources supplying or even replacing the traditional ways to generate the electricity has gained its interest. Due to the existing uncertainty of the renewable resources, an Energy Storage System (ESS) is one of the most crucial part in the concept of hybrid microgrid. An ideal ESS shall supply the missing load required when the renewable resources are unavailable. This study has integrated three types of batteries in the microgrid consisting of NCM Lithium-ion, Lithium Titanate (LTO), and Vanadium Redox Flow Battery. The model is designed and built according to the literature through MATLAB/Simulink® Software, the behavior of the batteries such as voltage, current and also the power are observed to determine the reliability of the system with stated configuration.

1 INTRODUCTION

The hybrid microgrid system in this study consisting of two renewable resources in which are Wind and Solar PV, accompanied with three ESS(s) to ensure the sufficient power supply during the zero-energy production of the renewable resources (An assumption of islanded mode). Where NCM Lithium-ion battery is subjected to 20% of the maximum load supply as the base, 70% owed to VRFB and the last 10% of overall power demand (assuming at peak) will be responsible by the LTO which excelled at rapid charging and discharging.

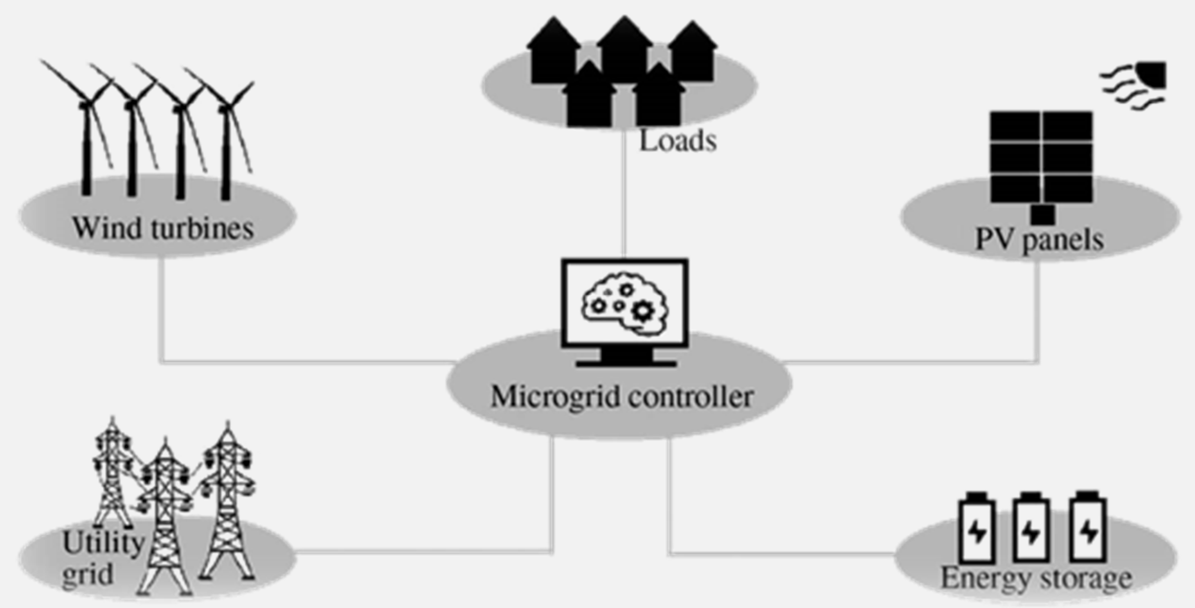

Figure 1: Layout of the studied system where an ESS consisting of three types

2 MODELING

An Equivalent Circuit Model(s) (ECMs) are used to represents the behavior of the ESS(s) as shown in figure 2. To verify the accuracy of the ECM, the comparison between the experimental data and simulation model are shown in figure 3 for VRFB. The result of the verification shows that the model fits the experimental data with minor error (maximum 6%) on the transition between charge and discharge current.

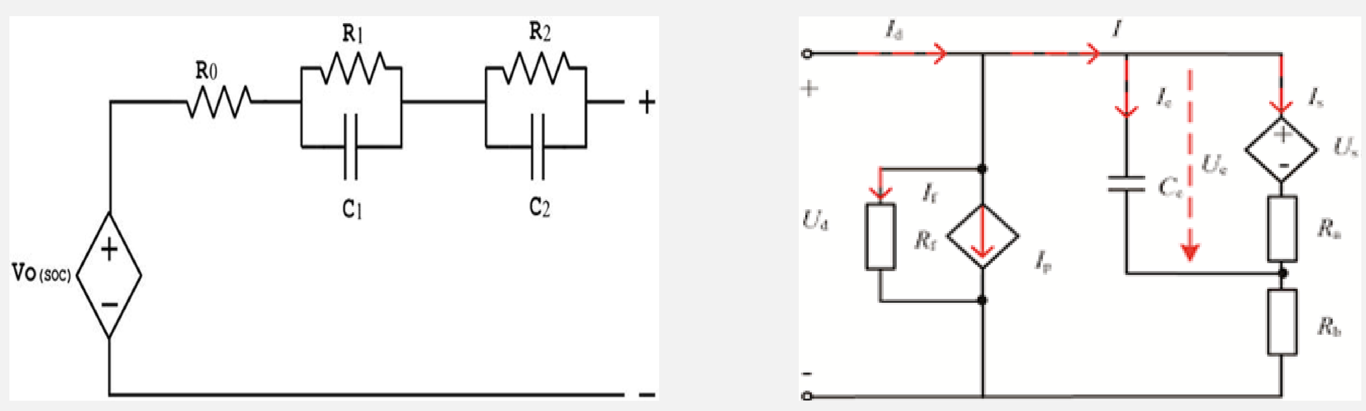

Figure 2: ECM(s) used to represents to battery's behavior during applied load, Lithium-ion (Left) and VRFB (Right)

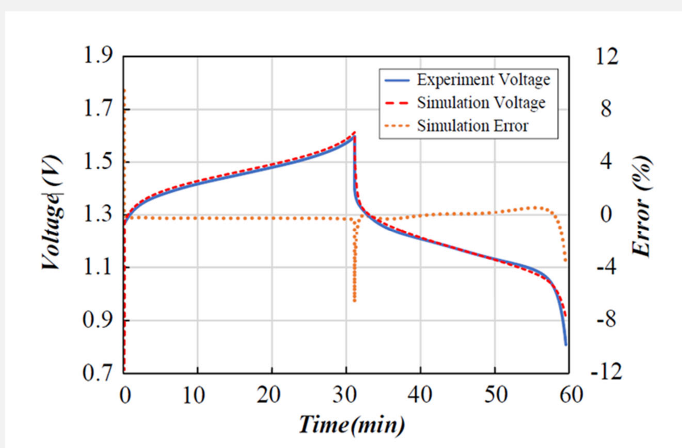

Figure 3: Comparison between simulation and experimental data of VRFB battery

3 METHODOLOGY

The simulation is done through MATLAB/Simulink®, the detailed ESS(s) are created and connected to the grid based on the Equivalent Circuit Models (ECMs) shown in figure 2 along with the other components such as utility grid and renewable energy sources. The sequences of charging and discharging the ESS(s) are determined by the input algorithm.

In this study, a NCM lithium-ion (Li3) ESS has been used for base load and limited to 100 kilo-watts, the excessive power required will be supply by the VRFB ESS which responsible for majority of the load requirement. And lastly the LTO ESS will be used in the last order due to the characteristics of LTO battery (in case of system failure or sudden power shortage).

As the renewable sources are available, the generated power will supply the required loads, thus, lowering the energy drawn from the grid, also, any excess energy produced will be use to charge the ESS(s).

With the mentioned approach, the expected result of this study is to observe the stability of the grid power, meaning that the power drawn from the grid shall remain its consistency throughout the simulation.

4 COMPONENT'S CAPACITY

The sizing of the study microgrid components are based on an assumption of islanded mode, whereas, the renewable resources and the energy storage systems shall supply the required load without relying on any energy drawn from utility grid. The table below show the sizing of microgrid components used in this study. In which, solar PV play a crucial role in renewable power production and VRFB as the largest energy storage system.

SYSTEM COMPONENT	RATING (kW)
SOLAR PV	750
WIND TURBINE	100
TYPICAL LITHIUM-ION	60
LITHIUM TITANATE (LTO)	45
VANADIUM REDOX FLOW (VRFB)	500

Table 1: Sizing of system's components

5 RESULT

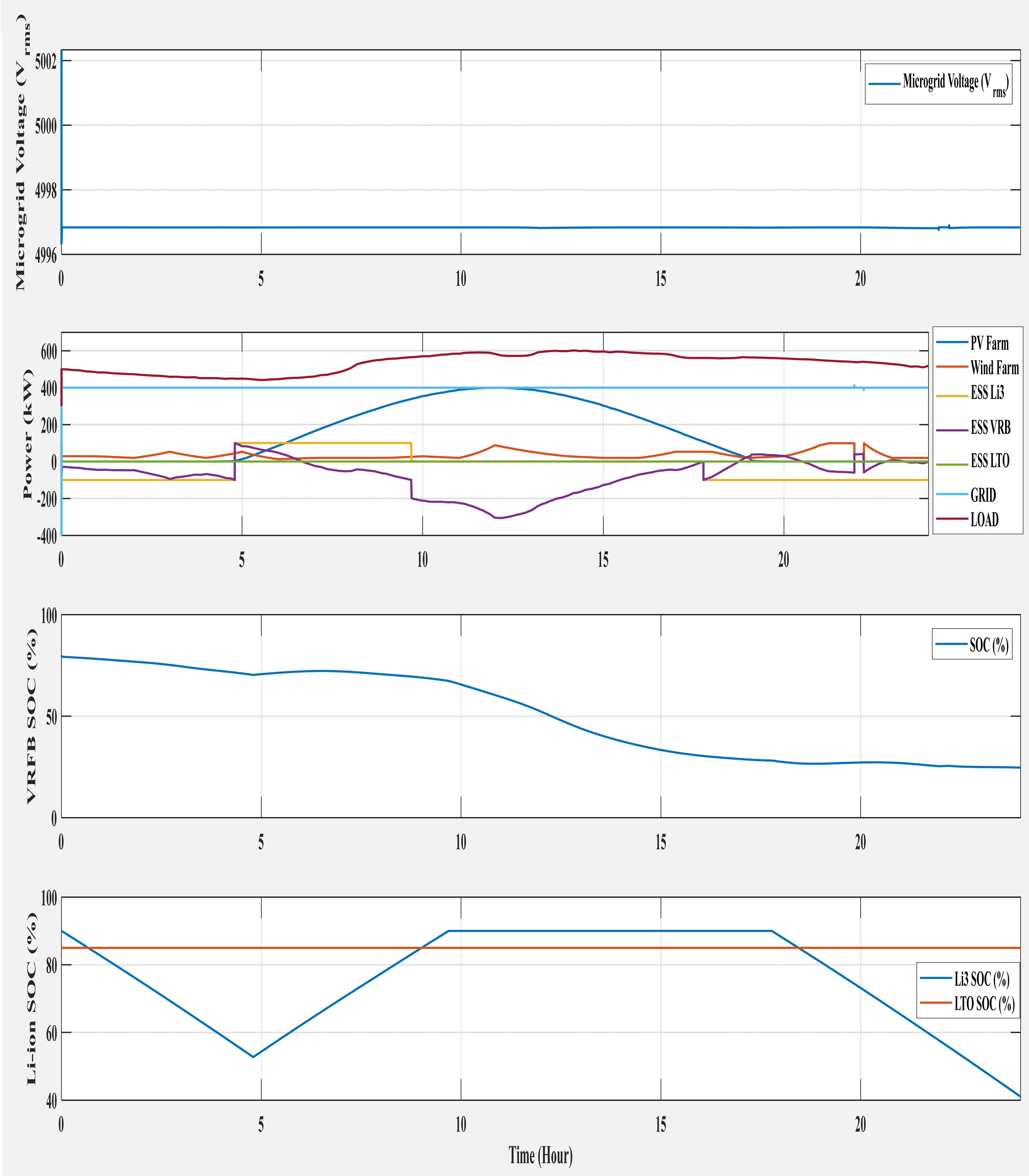

Figure 4: Simulation result Microgrid Voltage (First), Overall Microgrid Power (Second), VRFB's State of Charge (Third), and two Li-ion ESS(s) State of Charge (Fourth)

6 CONCLUSION AND OUTLOOK

From the result plot, the microgrid voltage and the power drawn from the grid shows the stability throughout the simulation indicates that the studied system is sufficient enough to supply the load without a peak (extra energy drawn from the grid). In the economical perspective, the cost of electricity varies in a day (off-peak and on-peak), meaning that, with the studied system, the cost of electricity is lower than the system without renewable sources and ESS. A more comprehensive approach is to set the algorithm to discharge the ESS(s) at higher rates during the peak time to further reduce the cost of electricity and make the system becomes more feasible.

As can be seen from the second to fourth result plot, for the ESS(s) the negative (-) values indicate the discharging process and vice versa for positive (+) values. The NCM (Li3) ESS discharge and charge according to the settled criteria where the maximum state of charge is 90%. As VRFB ESS is responsible for the majority of the load required it can be seen that the VRFB SOC keeps discharging throughout the simulation, While the LTO SOC remains constant due to no interruption was introduced.

An extension of this work is to design a more comprehensive algorithm to minimize the cost of electricity i.e., drawn lesser energy from grid during on-peak condition.

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