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Design of Hybrid System Power Management Based on Load Demand Using Operational Control System

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***Abstract*—Renewable energy is a limited energy source that involves of sunshine, wind, and water. It's normally used as sources of renewable power plants. Despite of its advantages, these power plants also contribute some disadvantages, such as high generation costs, highly dynamic behavior, etc. The disadvantages are being raised due to instability of the energy sources (RER). This study is aimed to design power management of a hybrid system based on operational control system based Artificial Neural Network (ANN) based on load demand. In this study, Power Management of Hybrid System used 3 power plants: Photovoltaic (PV), Wind Power, and Micro Hydro Power Plant (MHPP), while Battery was employed as storage system. Main focus of the work was to determine the activation of each plant using ANN method to fulfill the load demand. Matlab Simulink was employed to develop and simulate the ANN on the system. From results of simulation it can be concluded that ANN can reach target accuracy level in around 80%. When the entire plant was interconnected, the ANN experienced a misreading due to the voltage drop in each generator that affected input of the ANN.**

Keywords*—*operational control system, artificial neural network, hybrid system, load demand, energy management

I. Introduction

Renewable energy (RE) is an energy that has unlimited availability covering wind, sun and water which in its development can be used as a source of renewable power plant. This power plant has advantages such as low pollution, low operational costs and abundant resources, but also has disadvantages such as generous cost generation, difficult to generate due to the non-constant renewable energy resource (RER). Thanks to its superiority, research on the RE field is essential for future energy resources.

Photovoltaic (PV) or solar power plants have advantages such as abundant solar energy resources and low maintenance costs, but have disadvantages such as the irradiation of the sun. Wind Power or wind power plants also have advantages such as wind resources are abundant and environmentally friendly. As with PV, Wind Power also has a disadvantage due to wind resources that are not constant. To overcome the non-constant input, it can be used Micro Hydro Power Plant (MHPP) as auxiliary power plant with additional battery as storage.

A lot of studies on operational hybrid control system to optimize the power generated have been developed. As stated by Yusof [1], RER integration such as PV systems with diesel generators in hybrid power systems is widespread throughout the world thanks to its economic and technical aspects. Yusof used fuzzy logic to optimize battery usage based on state of charge (SOC) in order to back up the system when there is a lack of energy in PV and Wind Power. Then in [2], Trifkovic examined power management using 5 core components (PV, wind turbine, electrolyze, water storage and fuel cell) using predictive control model. While Lopez [3] was trying to minimize the costs by adding batteries. The rest of the studies using ANN [4], homer [5], IC [6], and others [7-9]. However, most of researchers have not discussed much on RERs with unstable sources.

In order to overcome some problems that caused by various value of RER, artificial intelligence method can be employed in order to analyze and predict the RER changes. Thus, the output from the plant will be more efficient and can cover load demand. Therefore, the method of Artificial Neural Network (ANN) is needed because this method can analyze and predict the changes that occur in RER using thoughts that approximate human thinking. Thus, the operational problems of these plants can be overcome.

Thus, the purpose of this study is to design a hybrid power management system for PV, Wind Power, and MHPP based on operational control system to meet load demand using ANN. Hopefully, this system can streamline the output from the hybrid power plant.

II. Method

The modeling system here aims to model each plant in order to operate in accordance with the intended objectives of the researcher. In general, diagram block of the whole system is expressed as in Fig. 1.

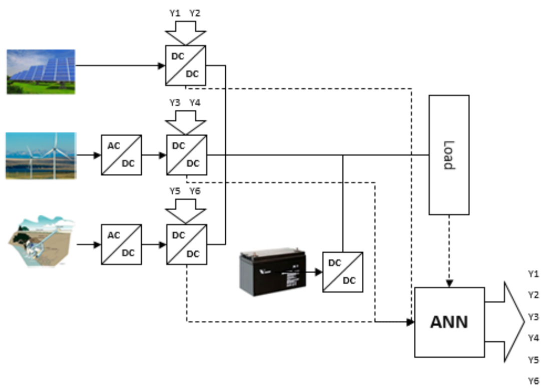

Fig. 1. Blog Diagram of Hybrid System

A. Converter Modeling

In this study, due to the different levels of source, as depicted in Fig. 1, 2 types of converters were prepared: buck converter and boost converter. It's assumed that levels of the energy sources can be below and upper the power demand. Such that the converters would be working in two differences mode depend on the condition of the sources.

The proposed boost converter was represented with the following formula:

$$V_{out} = \frac{V_{in}}{1-D} \tag{1}$$

$$Lmin = \frac{(1-D)^2 * D * R}{2 * f} \tag{2}$$

$$Cmin = \frac{D * Vout}{Vr * R * f} \tag{3}$$

Meanwhile the buck converter was modeled using the following formula:

$$D = \frac{V_{out}}{V_{in}} \tag{4}$$

$$Lmin = \frac{(1-D)^2 * R}{2 * f} \tag{5}$$

$$Cmin = \frac{(1-D) * Vout}{8 * Vr * L * f^2} \tag{6}$$

where:

$Vout$ = Output voltage (V)
Vin = Input voltage (V)
D = Duty Cycle (%)
$Lmin$ = Minimum Inductor Value (H)
$Cmin$ = Minimal Capacitor Value (F)
R = Resistor Value (Ω)
f = Switching frequency (Hz)
Vr = Voltage ripple (V)

B. *Modeling of PV System*

In PV system, the model was represented by using PV blocks parameters provided by Matlab with the following specifications [10]:

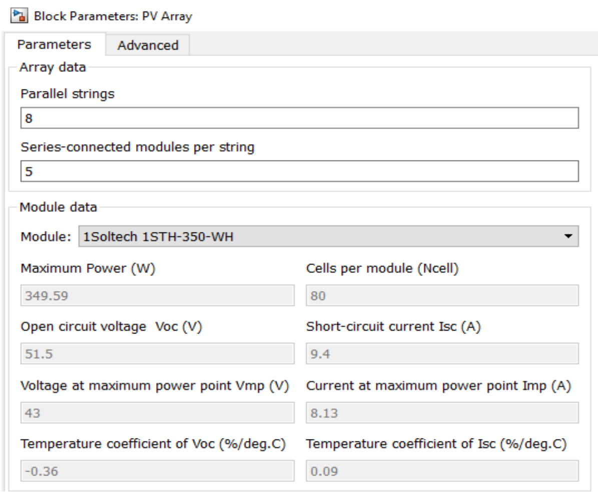

Fig. 2. PV Array Parameters

C. *Modeling of Wind Power*

In wind power, model of the system was formulated as follows [11]:

$$Pm = Cp\left(\tfrac{1}{2}\,\rho\, A\, V^3\right) \tag{7}$$

$$Tr = \frac{Cp\left(\tfrac{1}{2}\,\rho\, A\, V^3\right)}{\omega_R} \tag{8}$$

where:

Pm = Turbin Power (Watt)
Cp = Power Coefficient
ρ = Air Density (kg/m)
A = Turbine sectional area (m2)
V = Wind Speed (m/s)
Tr = Torque wind turbine (Nm)
ω_R = Wind turbine rotation speed (rad/s)

D. *Modeling of Microhydro*

In MHPP system, modeling was made simpler to reduce the complexity by using synchronous generators. Matlab Simulink block to represent the MHPP system model was designed as below [12]:

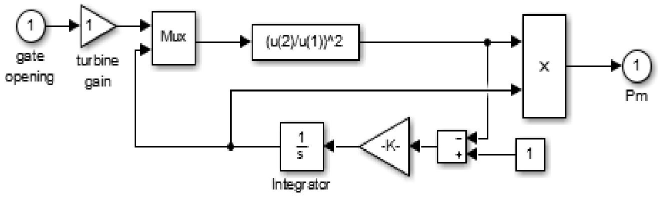

Fig. 3. Turbine Generator Modeling

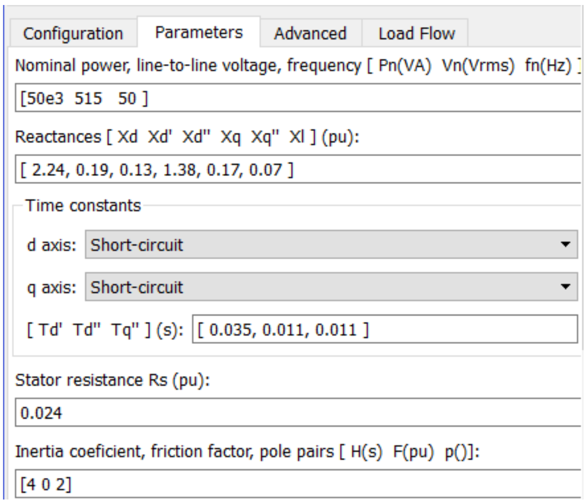

Fig. 4. Synchronous Generator Parameters

E. *ANN Modeling*

During the ANN modeling, there are 2 things to watch out for. First is the training data, the second is the test data. Training data is used to determine the weight value required by ANN, while the test data is used to validate the ANN output with the desired target. Here is the process of design ANN in Matlab Simulink:

1) Specify ANN input variable: As depicted in Fig. 5, ANN uses 8 inputs: time, V PV, P PV, V Wind, P Wind, V MHPP, P MHPP, and Load. V PV is voltage of PV, P VP is power of PV, V Wind is voltage of wind power, P Wind is power of wind power, V MHPP is voltage of MHPP, and P MHPP is power of MHPP. Y1-Y6 are output of the ANN. Each output represents the output of the generator.

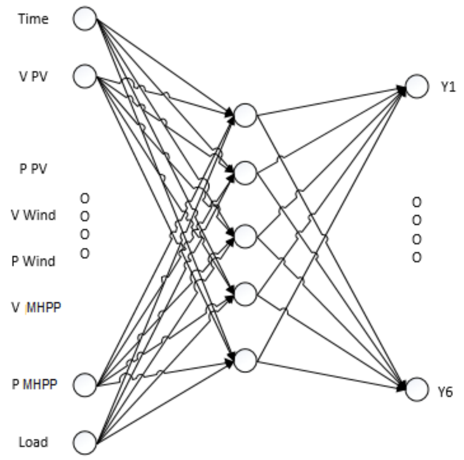

Fig. 5. ANN structure

2) Data Normalization: After getting the data from the desired variable, the next step is to normalize the data. Normalization of data is done by using the formula:

$$X' = \frac{0.8*(X-b)}{(a-b)} + 0.1 \tag{9}$$

where:

X' : Normalized Result Data
X : Original data/initial data
a : Maximum value of original data
b : Minimum value of original data

3) ANN Training: After normalizing the data, the next step is to train ANN using the normalized results data. After training ANN, ANN modeling will be obtained.

4) ANN Output Comparing: After obtaining ANN modeling from Matlab, the next step is to test to compare ANN output with target during training.

III. Results and Discussion

TABLE I shows the maximum power value of each generator created. In the PV system, there are 40 panels worth 350W that are arranged in parallel and series (8x4). Wind Power has a maximum power of 25 KW at a wind speed of 12m/s. While the MHPP runs constantly to power 50KW.

TABLE I. Power Configuration

Configuration	Total Power	Note
PV	13,2 KW	in 1000w/m^2
Wind Power	25 KW	in 12m/s
Micro Hydro	50 KW	Constant
Battery	12 KW	-

TABLE II. Target of ANN

No.	PV Out	PV Charge	Wind Out	Wind Charge	Micro Out	Micro Charge
1	1	0	0	0	0	1
2	1	0	0	0	0	1
3	0	0	0	0	1	0
4	0	0	0	0	1	0
5	0	0	0	0	1	0

TABLE III. Output of ANN

No.	PV Out	PV Charge	Wind Out	Wind Charge	Micro Out	Micro Charge
1	1	0	0	0	0	1
2	1	0	0	0	0	1
3	0	0	0	0	1	1
4	0	0	0	0	1	0
5	0	0	0	0	1	0

From TABLE II and TABLE III, it can be concluded that ANN output has an accuracy of 80%. From 5 experiments, the only 1 target that cannot be reached, (data number 3). This was happened because during the process of ANN in Matlab, data number 3 was very rare. When ANN looks for a weighted value, the weights match the data that often appears or can be called "Behavior Data". Thus, ANN can be inferred always looking for the weighted value of the dominant data.

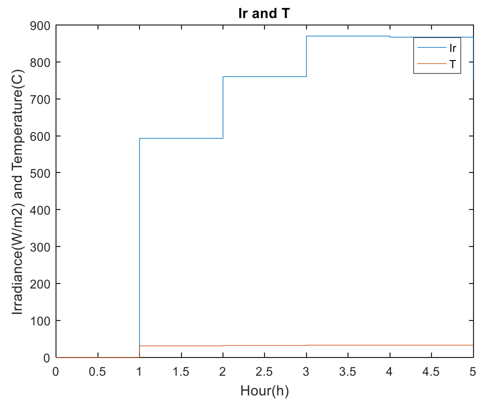

Fig. 6. Irradiance (Ir) dan Temperature Input (T)

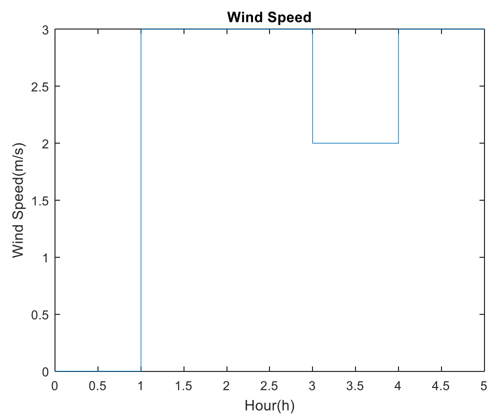

Fig. 7. Wind Speed Input

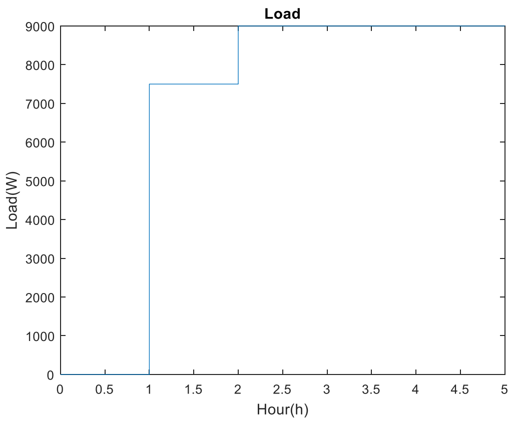

Fig. 8. Load Data

Fig. 6, Fig. 7 and Fig. 8 are the data used to test the management of the hybrid system. As seen at 2 to 5 the irradiance value of PV continues to rise from 600 W/m^2 to 900 W/m2, while the wind input was small. In wind power modeling, in order to produce maximum power required input of at least 10 m/s. In Fig. 9, the load value increases from 2 to 5 hours.

Outputs of the ANN of each source are explained as follows. The outputs are defined as Y1, Y2, Y3, Y4, Y5, and Y6. Y1 is the output of ANN for PV load, which indicates the PV runs to supply the load. Y2 is the output of ANN for PV charge, which means that PV runs to supply the battery. Where Y3 and Y4 are the output of ANN for wind power load and charge, respectively. While Y5 and Y6 are the output of ANN for MHPP load and charge, respectively, which means that MHPP are running to supply the load and to charge the battery, respectively. Value of the outputs always 0 or 1.

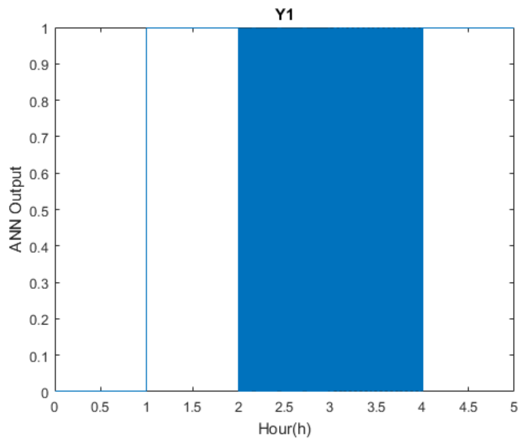

Fig. 9. Output of Y1 (PV Load)

Fig. 9 shows that Y1 often occurs switching from 0 to 1 from 2 to 4 hours. This occurs because the PV output was maximum and attempts to supply the load, but the PV output has been affected by the load (voltage drop occurs), so the switching on Y1 was not inevitable. While as seen in Fig. 10, Y2 was always zero due to insufficient PV power for charging.

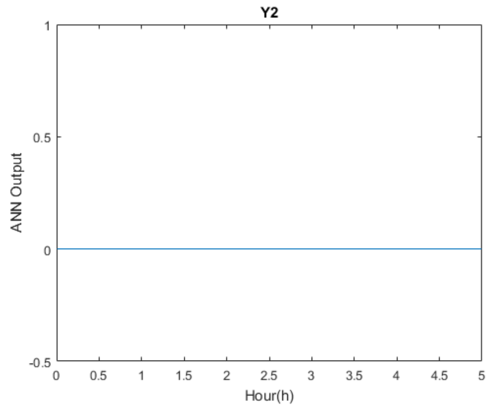

Fig. 10. Output of Y2 (PV Charge)

In wind power, the output power and the voltage were very small, because the wind velocity input cannot meet the cut-in zone. Such that, the turbine did not rotate and then the power of wind power cannot exceed the load demand. It caused Y3 and Y4 maintain zero, as depicted in Fig. 10 and Fig. 11.

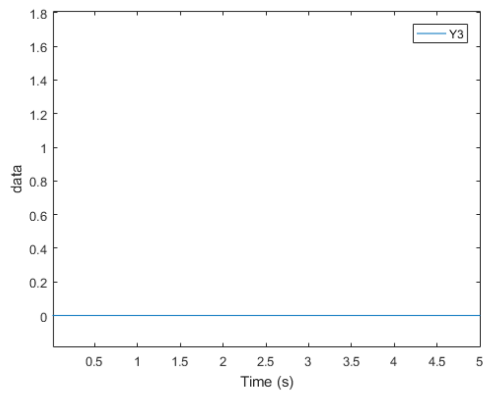

Fig. 11. Output of Y3 (Wind Power Load)

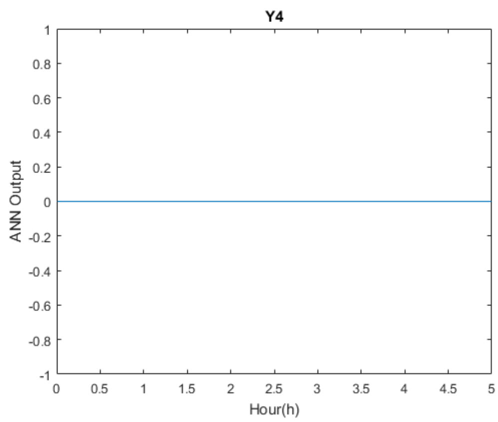

Fig. 12. Output of Y4 (Wind Power Charge)

Whereas, in Fig. 12, it can be seen that at 2 to 3 hours, Y5 had an output of 0. This occurs because the PV Power output was in good supply, which causes the MHPP to be off. When Y1 (PV) was on, MHPP (Y5) should not be on. This was equal to the target of ANN training. As shown in

Fig. 13, at 2 to 4 hours, Y6 was charging. But there was a lot of switching due to the effect of the load installed and the maximum PV output.

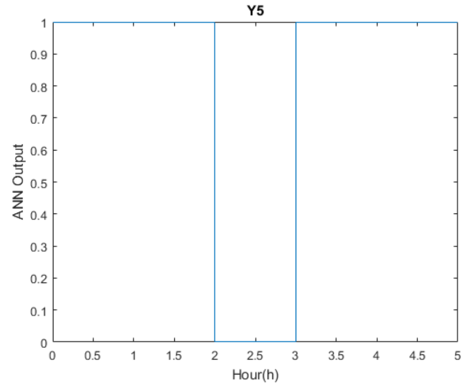

Fig. 13. Output of Y5 ANN (MHPP Load)

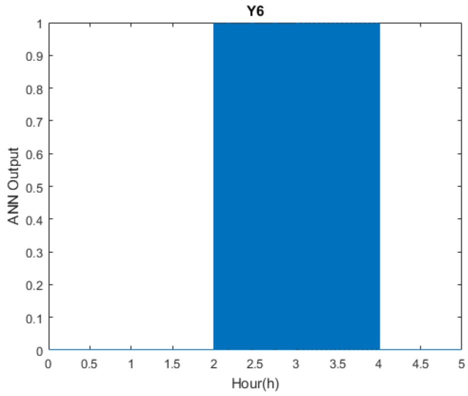

Fig. 14. Output of Y5 ANN (MHPP Charge)

Meanwhile, Fig. 14 and Fig. 15 show that PV has a voltage of 82V to 230V, but PV power can be maximized at 2 to 3 hours. While at 3 to 5 hours the PV power drops. This corresponds to Fig. 7, the Ir value rising from 760 W/m2 to 870 W/m2 from second to second to 3 which causes the PV power value to increase. When the clocks 3, 4 and 5 the value of Ir decreased from 870 W/m2, 861 W/m2, and 751 W/m2. But the load value (Fig. 9) at 3 to 5 hours is also increased, causing the PV to not supply the load. This causes the PV output to drop. However, as seen in Fig. 16, in wind power, the output power and voltage are very small, that cause the wind velocity input cannot meet the cut-in zone. Such that, the turbine did not rotate due to the low level of load demand of the power of wind power.

Fig. 17 shows instantaneous spikes during the 2nd, 3rd and 4th hours. This happens because of load changes. At the 2nd, 3rd and 4th hours there was load release and load connection, such that the time at which discharge and load connections occur together which causes instantaneous power spikes. Then, in Fig. 18, the voltage values of the MHPP are further down due to the increasing value of the load (Fig. 9) at 2 to 5.

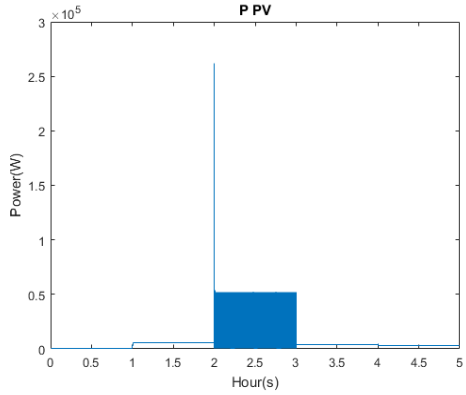

Fig. 15. Power Output of PV

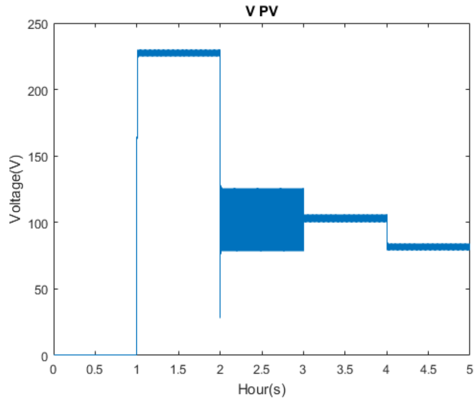

Fig. 16. Voltage Output of PV

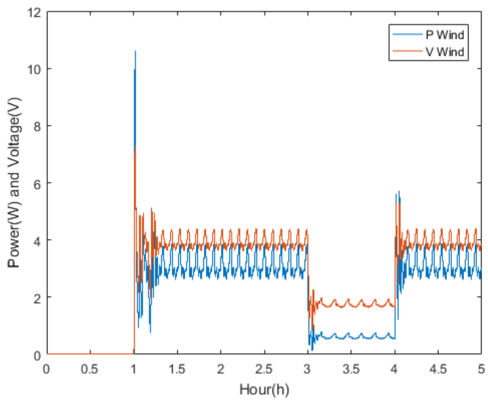

Fig. 17. Power Output and Voltage of Wind Power

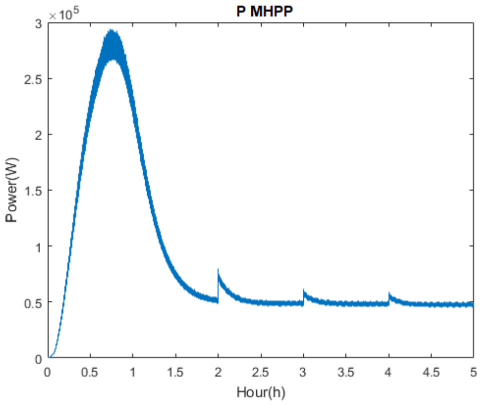

Fig. 18. Power Output of MHPP

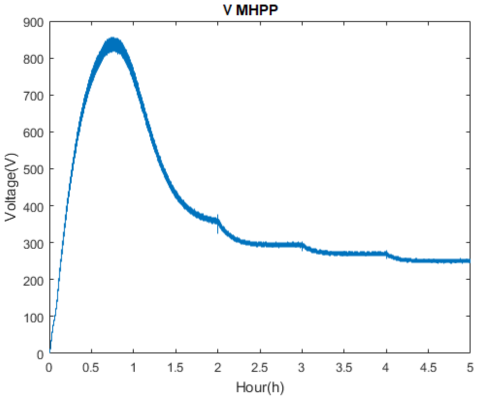

Fig. 19. Voltage Output of MHPP

IV. Conclusion

Hybrid power management system using operational control system based ANN has been successfully designed and simulated for the 3 types of renewable energy sources: PV, wind power, and MHPP. The findings conclude that the proposed hybrid system was met the load demand accuracy in around 80%. Moreover, the system also can supply the load on demand, despite of the changing of the sources condition. However, ANN had an error when the generator was interconnected with the load. This was due to the drop of voltage that caused the ANN to be misread. The present of this hybrid system method could be an alternative method to manage out power of renewable energy power plants.

Acknowledgment

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