LAPORAN AKHIR PENELITIAN
PENDIDIKAN BERBASIS LABORATORIUM
LABORATORY BASED EDUCATION (LBE)

DESAIN PEMBANGKIT LISTRIK PIKO-HIBRID (TENAGA ANGIN DAN SURYA) UNTUK DAERAH PEDESAAN

TIM PENGUSUL

Dr. Ir. Yusran, ST., MT.	**NIDN**	**:**	**0004047509**
Dr. Eng. Ir. Dewiani, M.T., IPM	**NIDN**	**:**	**0026106904**
Ir. Hasniaty A, S.T., M.T., Ph.D	**NIDN**	**:**	**0012057401**
Ir. Gassing, M.T.	**NIDN**	**:**	**0020076004**
Ir. Tajuddin Waris, M.T.	**NIDN**	**:**	**0024046702**
Irfan Fatahuddin, S.T.	**NIM**	**:**	**D032201002**
Muhajir Ahmad Sigi	**NIM**	**:**	**D041181301**

DEPARTEMEN TEKNIK ELEKTRO
FAKULTAS TEKNIK
UNIVERSITAS HASANUDDIN

2022

HALAMAN PENGESAHAN

Judul Penelitian		: Desain Pembangkit Listrik Piko-Hibrid (Tenaga Angin dan Surya) untuk Daerah Pedesaan
Ketua Peneliti		
	a. Nama Lengkap	: Dr. Ir. Yusran, S.T., M.T.
	b. Jenis Kelamin	: Laki-Laki
	c. NIDN	: 0004047509
	d. Jabatan Fungsional	: Lektor Kepala
	e. Jabatan Struktural	: -
	f. Fakultas/Departemen	: Teknik/Teknik Elektro
	g. Telepon/Fax/E-mail	: 08124181907/yusran@unhas.ac.id
Anggota Peneliti Dosen (1)		
	a. Nama Lengkap	: Dr. Eng. Ir. Dewiani, M.T.
	b. NIDN	: 0026106904
Anggota Peneliti Dosen (2)		
	a. Nama Lengkap	: Ir. Hasniaty A, S.T., M.T., Ph.D.
	b. NIDN	: 0012057401
Anggota Peneliti Dosen (3)		
	a. Nama Lengkap	: Ir. Gassing, M.T.
	b. NIDN	: 0020076004
Anggota Peneliti Dosen (4)		
	a. Nama Lengkap	: Ir. Tajuddin Waris, M.T.
	b. NIDN	: 0024046702
Anggota Peneliti Mahasiswa S2 (5)		
	a. Nama Lengkap	: Irfan Fatahuddin
	b. NIM	: D032201002
Anggota Peneliti Mahasiswa S1 (6)		
	a. Nama Lengkap	: Muhajir Ahmad Sigi
	b. NIM	: D041181301
Waktu Penelitian		: 1 (satu) tahun
Biaya		: Rp. 8.000.000,-

Makassar, 31 Agustus 2022

Mengetahui,
Ketua Departemen Teknik Elektro

Dr. Eng. Ir. Dewiani, M.T.
NIP: 196910261994122001

Ketua Peneliti

Dr. Ir. Yusran, S.T., M.T.
NIP: 197504042000121001

Menyetujui,
Wakil Dekan Bidang Akademik, Riset dan Inovasi

Dr. Amil Ahmad Ilham, S.T., M.IT.
NIP: 197310101998021001

Design of Solar and Wind Energy based Hybrid Power Plant

Yusran[1,a)], Virgiawan Rachman Daeng Ratte[2,b)], Resita Wati[2,c)], Zahir Zainuddin[1,d)], Dewiani[1,e)], Hasniaty[1,f)], Gassing[1,g)] and Tajuddin Waris[1,h)]

[1]Department of Electrical Engineering, Universitas Hasanuddin, Gowa, Indonesia
[2]Power Electrical Engineering Research Grup, Department of Electrical Engineering, Universitas Hasanuddin, Gowa, Indonesia

[a)] Corresponding author: yusran@unhas.ac.id

Abstract. The solar and wind energy in Indonesia has great potential to be utilized as resource of electrical power generation. Solar and wind energy-based power plant especially in distributed generation (DG) type can supply electrical power to the remote areas. The operation of solar and wind energy power plant which is highly dependent on the weather can be overcome by making a hybrid system. This research topic is design of solar and wind energy based hybrid power plant for rural areas. The research objectives are (1) to develop a hybrid power plant (solar and wind) prototype with microcontroller-based control system, (2) to obtain the performance testing results of hybrid power generation system. The method is designing, building and testing a hybrid power plant system prototype. The main components of system are: 10 Wp solar panel, 4 blade vertical wind turbine, 24 V DC generator, 12 V battery, arduino uno microcontroller and other supporting components. The test results show that the prototype has worked functional. The supplying power from power plant is determined by microcontroller command. When the power plant current is more than 0.1 A and the battery voltage is less than 14.7 V, the power will be supplied to the load and vice versa

INTRODUCTION

A number of rural and remote areas in Indonesia have not received electricity supply from The Indonesian State Electricity Company. This can be caused by the lack of electrical power availability and/or obstacles in electricity distribution installation construction. The construction of renewable energy-based distributed generation can be an alternative solution [1]. The potential of renewable energy for electrical generation in Indonesia is actually very large, like solar and wind energy. The power plant can operate stand alone in an isolated system.

FIGURE 1. Intensity of solar radiation at Indonesia [2]

The map of solar energy potential for in Indonesia is shown in Fig. 1. Indonesia's position in the equator makes solar energy very potential to be developed. The average energy can be produced is 4.8 $kWh/m^2/day$.

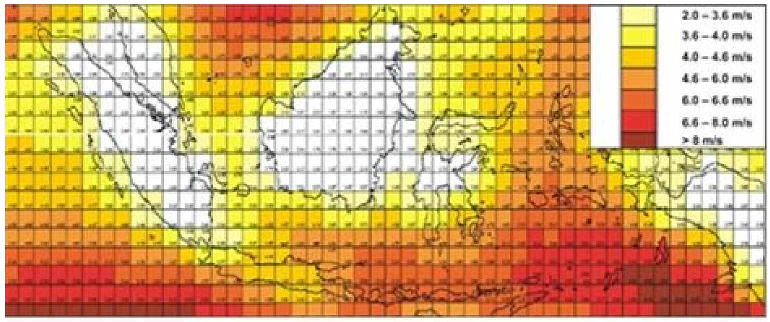

FIGURE 2. Map of wind potential at Indonesia [2]

The map of wind potential in Indonesia is shown in Fig. 2. It shows that the average wind speed in Indonesia is 2.5 to 6 m/s. It also shows that there are a number of areas that have relatively high wind potential, thus enabling the development of wind power plants on large scale. These areas include Sidrap Regency and Jeneponto Regency in South Sulawesi Province. The wind speed in the area is 6.0 to 8.0 m/s, even more. The wind speed in Indonesia is fluctuating. This means it can change drastically in fast time intervals.

This research topic is the design of hybrid power plants (solar and wind) for rural areas. The research location is in Taipa Hamlet, Soreang Village, Mappakasunggu District, Takalar Regency, South Sulawesi Province, Indonesia. The objectives of this study are (1) to develop a prototype of a hybrid power plant (solar and wind) with microcontroller-based control system, (2) to obtain the performance testing results of hybrid power generation system (solar and wind).

SOLAR PANEL, WIND TURBINE AND MICROCONTROLLER

The solar radiation energy can be converted into electrical energy by using photovoltaic panels or solar panels made of semiconductor materials. The semiconductor material made of a semi-metallic material. When it gets excitation energy from the outside, it will release its electrons [3]. This flow of electrons then creates an electric current and electron hole pairs. Types of solar cell are shown in Fig. 3.

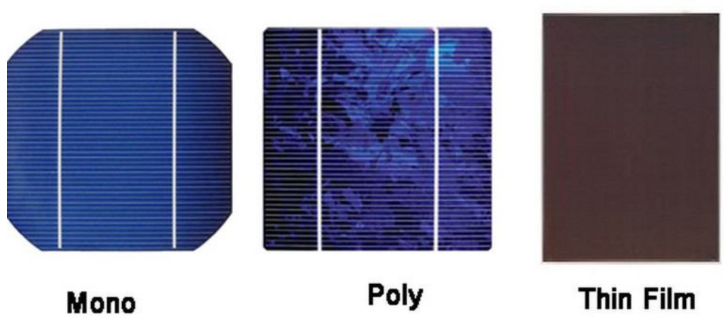

FIGURE 3. Types of photovoltaic cells [4]

The utilization of solar panel for power plant requires a planning by considering:

a) Amount of power required

b) Number of panels to be installed

c) Number of battery units required

The wind power plant converts wind energy into electrical energy using wind turbines. The wind energy serves to rotate a wind turbine coupled to a generator for electrical energy production. This electrical energy is usually stored in batteries before being utilized. The power produced by wind turbine depends on the diameter of the blades

[6]. Types of wind turbines are divided: horizontal axis wind turbines and vertical axis wind turbines. The vertical axis wind turbines have main rotor axis arranged perpendicularly. The turbine with vertical axis allows generator and gearbox to be placed near the ground. Actually, wind speed itself will be slower at low altitudes. Figure 4 shows the vertical axis wind turbine.

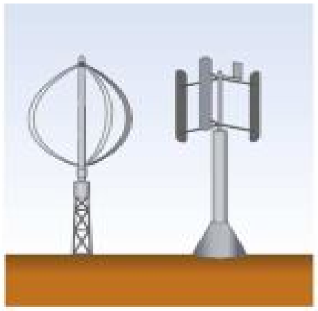

FIGURE 4. Vertical axis wind turbine [5]

The microcontroller is a functional computer system on a chip. It contains processor core, memory and input output equipment. Microcontroller is a digital electronic device that has input and output as well as control with programs that can be written and erased in a special way. Microcontroller is used to control electronic equipment, which emphasizes efficiency and cost effectiveness. Arduino uno is a microcontroller board based on the ATmega328. Arduino has 14 input/output pins. The 6 pins can be used as PWM outputs, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP head, and a reset button [7].

DESIGN OF HYBRID POWER PLANT SYSTEM

General Design

Based on NASA data, the research site has an annual average wind speed of 3.29125 m/s and an annual average solar radiation intensity of 18.7087 MJ/m2/day. The system design consists of main components: a 4 blade vertical axis wind turbine, a 24 volt DC generator and a 10 Wp photovoltaic cell, a microcontroller and other supporting equipment. This hybrid system combines solar and wind power plants with microcontroller control. The microcontroller will determine the power plant to charge the battery, alone or hybrid. The microcontroller can cut off the supply from the generator when the battery is fully charged (14.7 V) and reconnect with power plant when the battery is not fully charged. The microcontroller is also used to control the load based on time parameters.

Research Materials

The materials used in this research are:
a) Solar Module-Type Polycristal 10 Wp
b) Dynamo Mini Drill DC 24 V
c) Blades (from 4 inc PVC pipe)
d) Support Pole
e) Cable
f) Battery (capacity 5 Ah)
g) MCB (Mini Circuit Breaker)
h) Arduino Uno Microcontroller
i) 5 Watt lamp
j) Relay 5 V DC
k) IC Regulator
l) Diode In 4007
m) Voltage Sensor
n) Current Sensor (ACS712)
o) Micro SD Module

Power Design of Solar Panel and Wind Turbine

The average time of sunlight effectiveness on the tropics including Indonesia is assumed to be 5 hours/day. By using a 10 Wp solar panel, the maximum electrical energy generated in panel is 50 Wh. It is based on the following calculations:

$$E = P.t \quad (1)$$

which: E = electrical energy (Wh)
P = electrical power (W)
t = time (hours)
Thus, E = 10 Wp x 5 hours = 50 Wh

The solar panel uses a 10 Wp polycrystalin type. The maximum current capacity (I_m) is 2.90 A and the maximum voltage (V_m) is 17.6 V. The initial testing of panel is conducted by locating the panel outside the room for 1 hour to determine the amount of voltage generated. The test results show an increase in the initial voltage of battery (11.97 V) to 12.5 V. Figure 5 shows the 10 Wp solar panel and its specification.

(a) (b)

FIGURE 5. (a) 10 Wp solar panel (b) Specification of solar panel

If air with velocity v moves through an area of πR^2 (blade area), the power can be calculated using the formula:

$$P = \frac{1}{2} \rho \, v^3 \, \pi R^2 \quad (2)$$

which; P = power (Watt)
ρ = wind density (1 kg/m^3)
v = wind speed (m/s)
R = Diameter of the blade (m^2)

The average power of the wind turbine is calculated as follows
P = 0.5 x 1 kg/m^{3}x (3.26582 m/s)^3 x 3.14 x (0.5 m)^2
P = 0.5 x 1 kg/m^3 x 34.83186 m^3/s^3 x 3.14 x 0.25 m^2
P = 13.671505 Watt
P ≈ 13.7 Watt

Based on the above calculations, the average wind speed of 3.26582 m/s and a blade diameter of 50 cm will produce an average power of 13.7 W. The construction of generator DC and blade base is shown in Fig. 6. The construction of blades is shown in Fig. 7. The complete construction of the wind turbine is shown in Fig. 8. Based on individual wind turbine tests outdoor, the generated voltage is 5 Volts at a wind speed of 1.7 m/s. Thus, this wind turbine can generate voltage at relatively low wind speeds. Based on design power calculation, 1 unit of hybrid power plant has a maximum capacity of ± 60 Wh of electrical energy. Thus, 1 unit can only serve a maximum of 1 lamp with a capacity of 5 Watt for 12 hours.

FIGURE 6. Construction of the dynamo and blade base

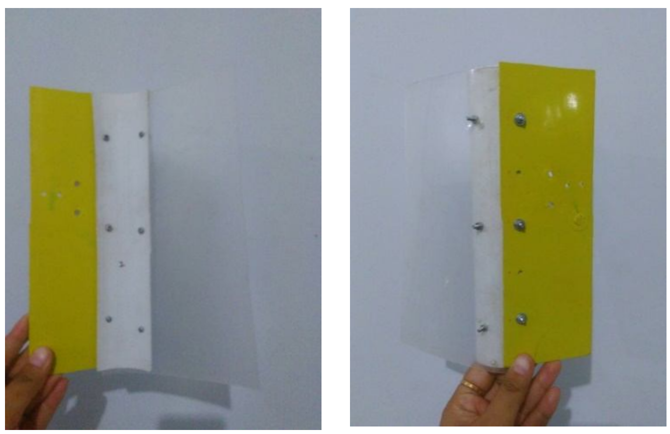

FIGURE 7. Blade construction

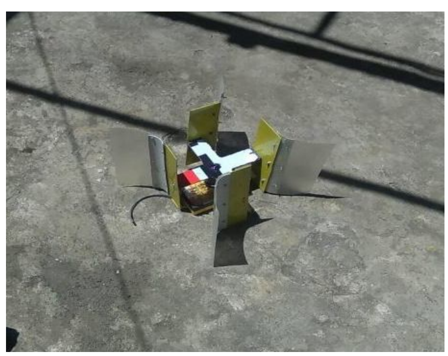

FIGURE 8. Wind turbine construction

Battery Selection

Battery has 12 V rating voltage and 5 Ah. current capacity. Based on the results of previous calculations, a maximum power of 60 W power and 12 V rating voltage will produce a current of 5 A. The battery storage capacity expressed in Watt-hours is calculated as follows

$$Wc = Ah \times V \times BF \tag{3}$$

which: $Ah = 5$ Ah
$V = 12$ volts
$BF = 1$
Thus,:
$Wc = 5 \times 12 \times 1 = 60$ Wh

Generation and Control System

The power output of the power plant is affected by the weather, which can change at any time. If one or both of power plant potential to produce electrical power, it will supply the power. The block diagram of hybrid power plant system is shown in Fig. 9. The block shows the two types of power plant installed in parallel and connected to charge control. The charge control is connected to the battery. The battery in this system will supply the load (lamp).

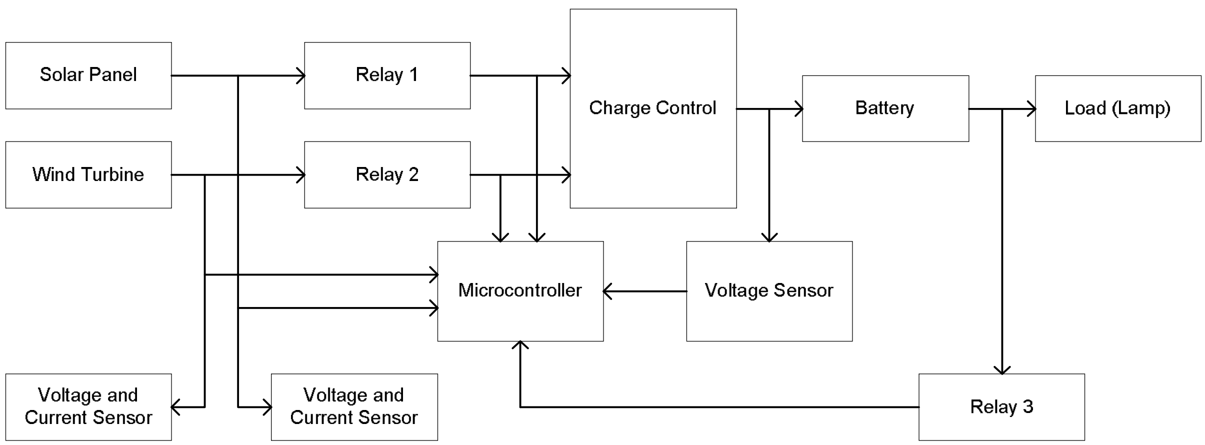

FIGURE 9. Block diagram of hybrid power plant system

Operation of Hybrid Power Plant System

The hybrid systems work to maximize power plant operations according to a predetermined scheme. The power generation system control scheme is shown in Fig. 10. The voltage sensors are mounted on generator and battery side. The current sensor is only installed on generator side. The relays on the system are controlled by microcontroller. The maximum and minimum battery voltage reference values are 14.7 V and 11.7 V, respectively. The 14.7 V value is the maximum battery voltage when charging. This value is chosen to keep the battery from being damaged quickly and not overcharging. The minimum battery voltage is 11.7 V when there is no supply from power plant.

The current reference value for solar panels and wind turbines is 0.1 A. The initial state of relay on power plant side is Normally Close (N/C). When, the current from solar panel and wind turbine is less than 0.1 A, relay will pick up from N/C to N/O. Thus, it does not supply power to the battery. Likewise, if power plant current is more than 0.1 A, it will supply power to the battery as long as battery voltage has not reached 14.7 V. When battery voltage has reached 14.7 V, the relay from the generator will work and cut off the supply, even if the power plant current is more than 0.1 A.

The load is connected to the relay with N/O initial condition. The on and off lamp time is set by microcontroller. At 18.00, relay changes position to N/C so that load is connected to system (lamp on). At 06.00, relay changes to the N/O position so that load will be deactivated (lamp off). The microcontroller is also programmed to read voltage and current values starting at 07.30 and repeating every 30 minutes.

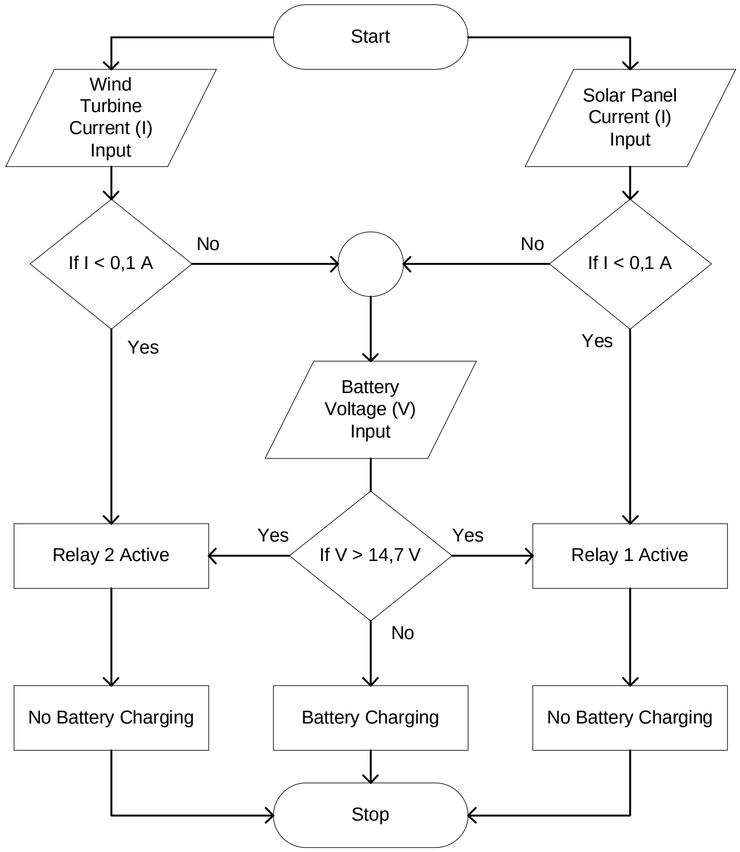

FIGURE 10. Power generation system control scheme

SYSTEM TESTING RESULTS

The testing purpose is to obtain current and voltage data (solar panel, wind turbine and battery), lamp status (on/off), power plant supplying the battery (solar panel, wind turbine, hybrid) and battery condition (full/not full). The test results are shown in Table 1. The test was carried out from 07.30 to 19.00 (middle Indonesian time). At 19.00: battery voltage is 14.43 V, solar panel current is 0.01 A and wind turbine current is 0.2 A. Based on these conditions, only wind turbine supplied power to battery. The relay on lamp side is in the N/C position. The battery then supplies power to load (lamp on).

TABLE 1. Testing result of hybrid power plant system

No	Time	Solar Panel		Wind Turbine		Battery	Lamp	Operation		Err.	Corr.
		Volt	Amp	Volt	Amp	Volt	ON/OFF	SP/WT/BF/ HYB	Relay		
1	07.30	13.06	0.22	0.52292	0.12	12.52	OFF	SP	2		
2	08.00	13.84	0.32	0.525	0.1	12.84	OFF	SP	2		
3	08.30	15.03	0.32	0.52292	0.14	15.18	OFF	BF	1, 2		
4	09.00	16.46	0.34	0.52292	0.1	14.41	OFF	BF	1, 2	X	SP
5	09.30	15.27	0.32	0.52292	0.1	14.45	OFF	SP	2		
6	10.00	16.46	0.33	0.52292	0.1	14.41	OFF	SP	2		
7	10.30	16.49	0.34	12.8	0.1	14.41	OFF	HYB	-		
8	11.00	17.51	0.34	12.8	0.25	15.09	OFF	BF	1,2		
9	11.30	16.34	0.34	12.8	0.3	15.13	OFF	BF	1, 2		
10	12.00	16.82	0.33	12.2	0.3	15.09	OFF	HYB	-	X	BF
11	12.30	16.68	0.3	15.37	0.3	14.38	OFF	HYB	-		
12	13.00	16.46	0.32	0	0	15.18	OFF	BF	1, 2		
13	13.30	16.49	0.33	0.51042	0.2	14.41	OFF	BF	1, 2	X	HYB
14	14.00	17.14	0.34	12.15	0.2	15.18	OFF	HYB	-	X	BF
15	14.30	17.44	0.34	0.51042	0.2	14.45	OFF	BF	1, 2	X	HYB
16	15.00	17.34	0.43	12.2	0.2	15.13	OFF	BF	1, 2		
17	15.30	16.38	0.32	15.37	0.5	14.43	OFF	HYB	-		
18	16.00	16.71	0.3	15.37	0.4	14.38	OFF	HYB	-		
19	16.30	16.27	0.1	12.15	0.2	14.45	OFF	WT	1		
20	17.00	14.45	0.34	12.15	0.2	15.18	OFF	BF	1, 2		
21	17.30	14.9	0.01	0.51944	0.1	14.45	OFF	BF	1, 2	X	NCH
22	18.00	12.06	0.01	12.1	0.2	14.43	ON	WT	2, 3		
23	18.30	12.06	0.01	12.1	0.2	14.45	ON	WT	2, 3		
24	19.00	12.06	0.01	12.1	0.2	14.43	ON	WT	2, 3		

SP=Solar Panel, WT=Wind Turbine, BF=Battery Full, HYB=Hybrid, NCH=No Charging, Err.=Error, Corr.=Correction

Figure 11 shows the voltage profile on solar panel and wind turbine. For solar panel, voltage at 07.30 is 13.06 V and continued to increase until it reached 16.46 V at 09.00. At 09.00 - 17.30 the voltage is 14.45 - 17.51 V. The highest voltage occurs at 11.00 (17.51 V). After 17.00 hour, the voltage decreases because the sunlight gradually disappearing. For wind turbine, at 07.30 - 10.30, voltage is constant around 0.5 V. At 11.00 - 16.30, voltage fluctuates due to the changing wind speed. The highest voltage of 15.37 V occurred at 12.30, 15.30 and 16.00.

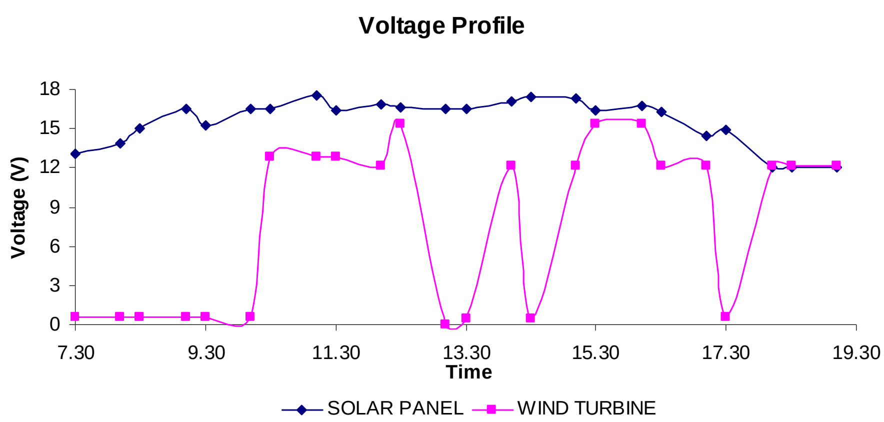

FIGURE 11. Solar panel and wind turbine voltage profile

Figure 12 shows the current profile on solar panel and wind turbine. For solar panel, at 07.30 to 16.00, current varies from 0.22 A – 0.34 A. A decrease in current occurs from 17.30 (0.01 A). This is caused by the sunlight gradually disappearing. For wind turbines, current also fluctuates from 0.01 – 0.4 A throughout the day. The highest current of 0.4 A occurred at 16.00. For 18.00-19.00 hour, current flows with 0.2 A constant value.

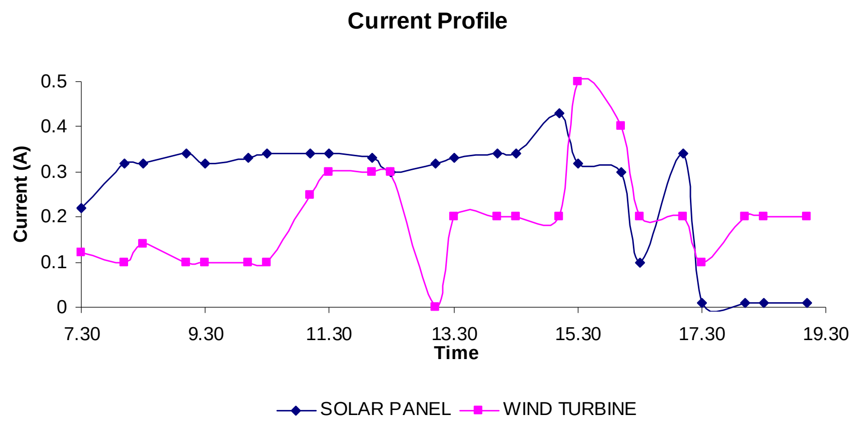

FIGURE 12. Solar panel and wind turbine current profile

CONCLUSION

The hybrid power plant prototype has generated electrical power for load supplying. The lowest and highest voltages on solar panels are 12.06 V and 17.51 V, respectively. Meanwhile, the lowest and highest current are 0.0001 A and 0.43 A, respectively. For wind turbines, the lowest and highest voltage is 0 V and 15.37 V, respectively. The lowest and highest current of wind turbine is 0.001 A and 0.57 A, respectively. The microcontroller has worked to control generation and load systems. The power plant supplies the battery when current is more than 0.1 A and battery voltage is less than 14.7 V. If one or both of these conditions are met, the power plant does not supply power to the battery. The microcontroller also managed to set the on and off time of the load (lamp).

REFERENCE

1. Y. Yusran, Y. A. Rahman, I. C. Gunadin, S. M. Said, S. Syafaruddin, *Mesh Grid Power Quality Enhancement with Synchronous Distributed Generation: Optimal Allocation Planning Using Breeder Genetic Algorithm*, PrzegladElektrotechniczny **1**, 82-86 (2020)
2. S. Armi, *Potential Of Wind and Solar Energy in Indonesia (ind)* (Geography ITB, Bandung, 2006)
3. J. Sigh, *Semiconductor Optoelectronics Physics and Technology* (Mc. Graw Hill, Inc, Singapore, 1995)
4. www.scribd.com August 2008. Photovoltaic (PV) System Design.
5. Fateta, *Wind Energy (ind)* (IPB, Bogor, 2004)
6. S. Pikatan,, *Wind Conversion Resume (ind)* MIPA Seminar, University of Surabaya. Surabaya, 1999
7. A. Kadir, *From Zero to Pro Arduino* (Andi Publisher. Yogyakarta, 2015)