Research Collaboration of ITENAS Bandung – Indonesia and MATE Godollo – Hungary on the Photovoltaic Thematic Field: Achievements and Future Plan

Dani Rusirawan[1*], *Liman* Hartawan[1], *Lita* Lidyawati[2], *Monika* Bozikova[3], *Zuzana* Hlavacova[3], *Martin* Libra[4], *Istvan* Seres[5], *Piroska* Vig[5], and *Istvan* Farkas[5]

[1]Department of Mechanical Engineering, Faculty of Industrial Technology, Institut Teknologi Nasional Bandung, Jl. PH. H. Mustofa No 23 Bandung, 40124, West Java, Indonesia
[2]Department of Electrical Engineering, Faculty of Industrial Technology, Institut Teknologi Nasional Bandung, Jl. PH. H. Mustofa No 23 Bandung, 40124, West Java, Indonesia
[3]Department of Physics, Institute of the Electrical Engineering, Automation, Informatics and Physics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Slovakia
[4]Department of Physics, Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic
[5]Institute of Technology, Hungarian University of Agriculture and Life Sciences, Páter K. u. 1., Gödöllő, H-2100 Hungary

Abstract. Since the agreement was signed officially in 2013, Institut Teknologi Nasional Bandung (ITENAS Bandung) – Indonesia and Hungarian University of Agriculture and Life Sciences (MATE Godollo) – Hungary have implemented a lot of scholarly activities, and one of them is research collaboration in the field of solar energy, especially in the thematic field of photovoltaic (PV). A set of experimental facilities has been developed and constructed to support related research. Basic facilities to understand the principle of electricity generated by PV, i.e., having the solar power plant (SPP) laboratory scale have been fulfilled by both universities. MATE Godollo has a 10 kWp SPP installation and uses polycrystalline and amorphous silicon PV modules, meanwhile, ITENAS Bandung has 1 kWp SPP and uses monocrystalline silicon PV modules. In this paper, a set of activities related to PV research collaboration between ITENAS Bandung and MATE Godollo will be elaborated, including the output and the outcome of the activities, and plan activities involving other university partners, Slovak University of Agriculture in Nitra – Slovakia and Czech University of Life Science Prague, Czech Republic.

1 Introduction

Solar energy research activities at the ITENAS Bandung, especially at the Department of Mechanical Engineering, formally were initialized in 2006, and the first activity was

* Corresponding author: danir@itenas.ac.id

installing the small-scale hybrid system of photovoltaic (PV) and WECS (Wind Energy Conversion System) using the Savonius rotor. The focussed of this research was realizing the installation of a hybrid system (PV and WECS) as the final project theme of Bachelor students. The capacity of a hybrid system was not emphasized but electricity generated simultaneously was the main concern at that time.

Meanwhile, the collaboration of ITENAS Bandung and universities abroad has been registered in the database of ITENAS Bandung, initialized formally in 2007 (although previously there was a lot of other significant collaboration), when MATE Godollo invited ITENAS Bandung's Faculty staff, to be involved in the research activities in MATE Godollo, especially in the thematic field of photovoltaic (PV). Nevertheless, research intensively in this thematic field was implemented in 2013, after an official partnership between ITENAS Bandung and MATE Godollo, was signed [1][2]. In fact, since that time a lot of activities in terms of joint activities (such as joint research, joint publications, joint conferences, joint workshops, and joint curriculum) and faculty-student mobility (conference keynote speaker and speaker, international credit transfer, workshop, etc.) have been carried out, reciprocally with mutual benefit.

In this paper, a set of activities related to PV research collaboration between ITENAS Bandung and MATE Godollo will be elaborate, including the output and the outcome of the activities, and plan activities involving other university partners, Slovak University of Agriculture in Nitra – Slovakia, and Czech University of Life Sciences Prague, Czech Republic.

2 Research collaboration in the thematic field of PV

Since the partnership agreement between ITENAS Bandung and MATE Godollo was signed officially in 2013, a lot of scholarly activities have been implemented, and a summary of all the activities, in general, can be listed as follows [1]:

1. Carried out the research in the thematic field of PV by joint research, data exchanges, and joint publications. The outcome based on this research type was 80 publications which consisted of the book of abstracts, the conference proceedings, monographs, and journals (included in a Hungarian journal);
2. Performed the international mobility program for the students through the international credit transfer, and output from this program, 19 students got an experience study in the campus of MATE for 1 semester. Additionally, one of the students took part in the MSc program until graduated. The international mobility program for the faculty staff is performed through the short stay program to enhance their qualification/program development of academic staff. Three academic staff was participated in the international workshop and international week);
3. Established and involved/participated in the international scientific forum/meeting: Developed the idea/initiated the ITENAS Bandung international scientific forum through the Faculty of Industrial Technology International Congress/FoITIC (biennial event); Participated actively in the International Workshop on Energy Environment Workshop (annual event), International Workshop for Young Scientist "BioPhys Spring/BPS" (annual event), etc.;
4. Hold the internationalization/harmonization of curriculum (case study for MSc program of Mechanical Engineering). The outcome of this activity is ITENAS Bandung and MATE Godollo plan to establish a Double Degree in the MSc Mechanical Engineering Program;

5. Hold the capacity building of the institution through the co-work of the competitive grant proposals (Indonesian Higher Education Grant, international grant, Erasmus+, etc.);
6. Supported the faculty staff in both universities to participate as adjunct lecturers/researchers/professors at the overseas university partners, to support teaching-learning processes.

2.1 Installation of a 1 kWp solar power plant (SPP) at the ITENAS Bandung

Related to research collaboration activities in the PV field, intensive research has begun since ITENAS Bandung installed a small-scale solar power plant (SPP) system. A 1 kWp (Wp = watt peak) grid-connected system of the SPP was constructed in 2018 with main components consisting of PV modules (crystalline technology) and an inverter. The surface orientation of the PV modules was 12º for the tilt angle and the position facing to the North (Rusirawan et al., 2019). The small scale of the SPP installation is shown in **Fig. 1**. [3]

PV modules of the 1 kWp SPP

Inverter of the 1 kWp SPP

Fig. 1. The main components of 1 kWp of SPP at the campus of ITENAS Bandung.

The main specifications of the 1 kWp SPP can be seen in **Table 1.** [4]

Table 1. The specification of 1 kWp SPP

PV modules - Monocrystalline Silicone type JAM6 60-265	
PV module electrical parameters	
Reted Maximum Power at STC (W)	265
Open Circuit Voltage (Voc/V)	38.26
Maximum Power Voltage (Vmp/V)	31.11
Short Circuit Current (Isc/A)	9.00
Maximum Power Current (Imp/A)	8.52
Modul Efficiency (%)	16.21
PV module operation condition	
Max. system voltage	DC 1000 V (IEC)
Operating temperature	-40ºC - +85ºC
NOCT (Nominal Operating Cell Temperature)	45 ± 2ºC
Inverter model UNO 2.0 TL OUTD	

Input Inverter specification		Output Inverter specification	
Maximum Input voltage (DC)	600 V	Output voltage (AC)	230 V
Input start-up voltage (DC)	100 – 300 V	Output Current Maximum (AC)	12.5 A
Input Current Maximum (DC)	12.5 A	Output Power Maximum	2200 W
Input Power Maximum (DC)	2200 W		

Some of the research installations are shown in **Figs. 2-3.**

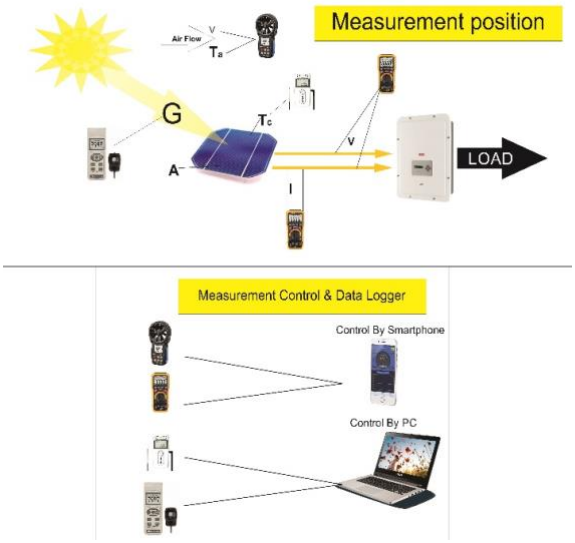

Fig. 2. The measuring system and data logger system of 1 kWp of SPP at the ITENAS Bandung.

Based on **Fig. 2**, it can be seen that the parameters that are needed to evaluate the SPP performance (both in view energy or exergy/availability) can be divided into 2 sides, i.e., input side: irradiation (G), velocity (v), ambient temperature (T_a), and cell temperature (T_c); and output side: current (I) and voltage (V).

2.2 Solar Power Plant (SPP) cooling system

The SPP's water cooling system as shown in **Fig. 3.**, is developed and tested to verify that at the lower temperature, the performance of the PV modules is increased. It is known that based on the general PV module characteristics, at the constant irradiation, the performance of a PV module is better at the lower temperature.

The SPP's cooling system consisted of the equipment as follows: (1) Temperature sensor, (2) water spray, (3) water reservoir (4) flexible hose, and (5) water collector. [6]

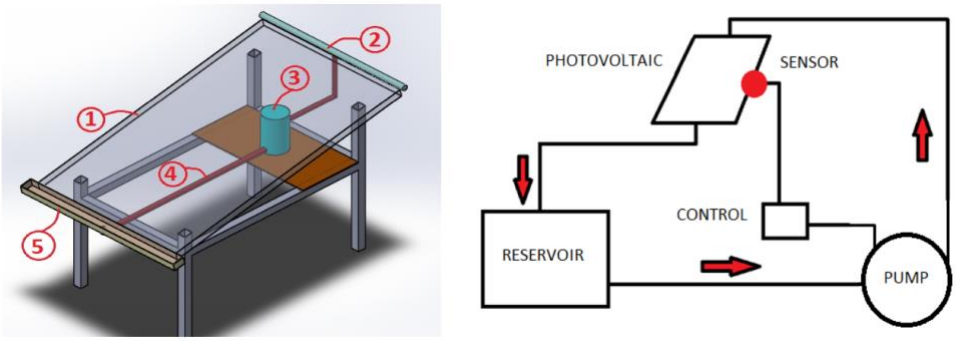

Fig. 3. The schematic diagram of SPP's cooling system (components – flow – control).

The control components of the SPP's cooling system were Arduino UNO, temperature sensor LM35, relay module, water pump, and adapter, as shown in **Fig. 4.** [5]

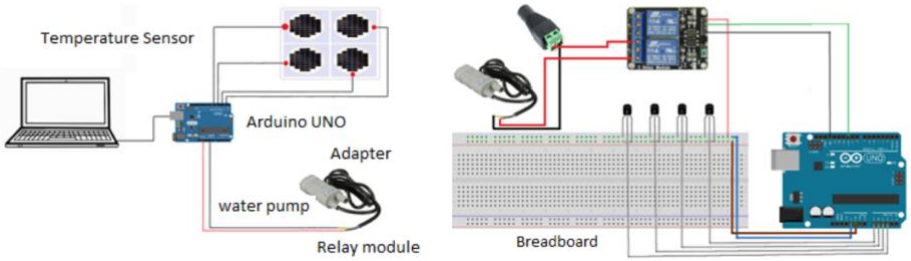

Fig. 4. The schematic diagram of SPP's cooling system.

The open cycle type is applied in the installation of SPP's cooling system, using pumps, reservoirs, hoses, and an Arduino UNO-based control system. The temperature is used as the control system parameter, and the ON-OFF pump works based on the temperature limits (upper and lower temperatures).

2.3 Research in solar power plant (SPP) modelling

Refer to the existing 1 kWp SPP, some research activities in modelling have been performed, and some of the research themes are [6]:

- Modelling of the PV module's characteristic based on single and double diode models using Visual Basic for Application (VBA) Microsoft Excel and SIMULINK;
- Modelling of the PV module's characteristics by implementing Fuzzy Time Series (FTS) algorithms;
- Modelling of the SPP energy production using Seasonal Autoregressive Integrated Moving Average (SARIMA) Algorithm;
- Modeling of the PV energy production using Machine Learning (Naive Bayes and Support Vector Machine Algorithms).

One of the outputs of the research in PV modelling, is shown in the **Fig. 5.**

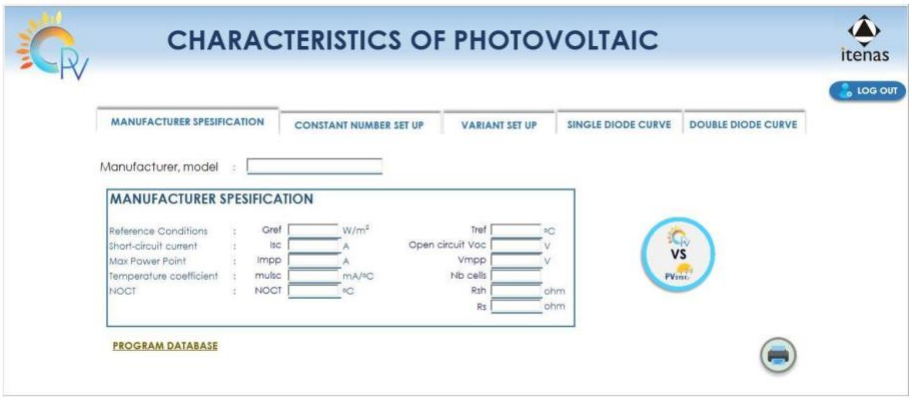

Fig. 5. The feature of the Cpv software.

Fig. 5 shows the main feature of the Cpv (Characteristic photovoltaic) software, which is developed using single and double-diode models.

In this research, the effort is emphasized on creating the PV module characteristics (I-V-P) using the Visual Basic Application (VBA) Microsoft Excel platform. This research product is called the Cpv (Characteristic of photovoltaic) software. By using the Cpv, the model of PV module characteristics can be predicted, using both single or double-diode models. In addition, The PV module characteristics resulting from PVSyst commercial software are used as a reference to find a suitable model resulting from Cpv and PVSyst.

Other modelling research work focussed on predicting future data based on previous (historical) data, especially output PV parameters (V-voltage, I-current, P-power) using the Fuzzy Time Series algorithm; Prediction of PV energy production using Seasonal Autoregressive Integrated Moving Average (SARIMA) Algorithm, and Machine Learning (Naive Bayes and Support Vector Machine Algorithms).

2.4 Current research

Presently, some ongoing research activities, as implementation collaboration ITENAS Bandung and MATE Godollo are as follow;

- Development of prototype solar tracker system using Arduino microcontroller;
- Development of agrivoltaic system, includes semi-transparent photovoltaic (at the ITENAS Bandung and MATE);
- Development of an Organic Rankine Cycle power plant using solar energy heat source (at the ITENAS Bandung and MATE);

3 Future collaboration in the thematic field of PV

A great relationship between ITENAS Bandung with some institutions in the Visegrad Four countries (Hungary, Slovakia, Czech Republic, Poland) should be accompanied by various activities, and one of them can be extended through the research collaboration in PV themes. The connectivity of the Visegrad Four countries is shown in **Fig.6.**

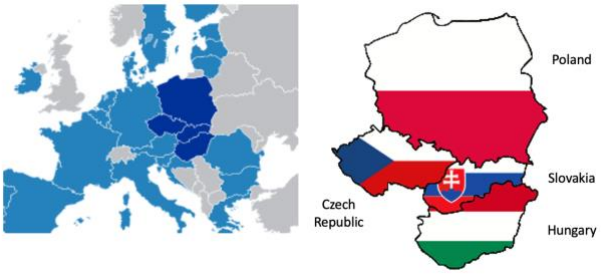

Fig. 6. The feature of the Cpv software.

Two other universities in the Visegrad Four, the Slovak University of Agriculture in Nitra (Slovakia) and the Czech University of Life Sciences Prague (Czech Republic) have the same research theme in the thematic field PV and, therefore research collaboration in the PV field should be implemented through joint research, joint supervision, joint publication, etc.

This year, two additional milestones have been reached by ITENAS Bandung, i.e.:

1. Recognized of ITENAS Bandung as one of the committee/organizers of the international workshop for young scientists "BioPhys Spring", June 15-16, 2023, as can be seen in **Fig. 7.**
2. Signed MoU partnership between ITENAS Bandung and Slovak University of Agriculture in Nitra, in August 24, 2023 (Nitra) and September 15, 2023 (Bandung)

Fig. 7. The international workshop for young scientist “BioPhys Spring 2023”.

4 Concluding remarks

A great partnership between ITENAS Bandung and MATE Godollo (Hungarian University of Agriculture and Life Sciences) can be recognized as the bridging step of ITENAS Bandung to gain further networking with institutions abroad, especially in the European countries.

Further research in the PV thematic field can be extended not only between ITENAS Bandung and MATE Godollo, but involves also the Slovak University of Agriculture in Nitra, and the Czech University of Life Sciences Prague, which is in great relation to MATE Godollo.

Through international collaboration, it is to be sure that the academic atmosphere of all institutions will increase, and strongly contribute not for the national education level, but also to global education.

This research project is carried out as a multidisciplinary international partnership between ITENAS Bandung, Indonesia, and MATE Gödöllő, Hungary.

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