Konsorsium PETUAH (Perguruan Tinggi Untuk Indonesia Hijau)

Pengetahuan Hijau Berbasis Kebutuhan dan Kearifan Lokal untuk Mendukung Pembangunan Berkelanjutan (*Green Knowledge with Basis of Local Needs and Wisdom to Support Sustainable Development*)

TECHNICAL REVIEW

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Renewable Energy Generation at Udayana University

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BACKGROUND

Based on data issued by PT PLN, in October 2015, the electrification ratio of Indonesia is approximately 87% [1]. This ratio is considered low, which is mainly due to the nation's demography. The nation consists of thousands of islands, hence developing a national electricity network requires a very high investment cost. In addition, power generation in Indonesia is mostly from fossil fuel with a limited reserve.

Contrary, the potential of renewable energy (RE) resources in Indonesia is very high [2,3]; hence becomes a prospective source for power generation. A number of government policies have been established to accelerate the use of renewable energy sources for electric power generation. The government has targeted 23% of the national energy mix is from renewable energy, by the year 2025 [4]. The program is supported by the government of Bali province by a declaration of the green province.

The utilization of RE sources for electricity generation, however, is subjected to a number of difficulties related to the nature of the RE. The available RE is highly dependent on the weather and global climate. A sudden weather change has a consequence of a sudden output change of the generated power. The intermittent energy supply from Renewable Energy (RE) generation to the grid has been known as the major cause of decreasing the reliability of the grid.

Recently, a smart control system has been developed to control a power grid supplied from a number of different generating systems. A smart grid system has been proven to be able to control the injected power from RE generating systems into the grid. The application of the smart grid system then has been increasing widely not only for a large-scale power grid but also for a small-scale grid, known as a smart microgrid system.

Udayana University Jimbaran Campus is located in the South part of Bali. The campus area covers about 250 hectares. This large area provides a wide opportunity to apply RE power generation, particularly solar and wind energy. The application of RE power generation within the campus area certainly will participate in the reduction of global GHG emissions. In addition, the existence of the equipment of the RE power generation in the university will also extend the opportunity for lecturers, researchers, and students in advancing their research in RE development.

An implementation of RE power generation pilot project has been planned at Udayana University. The pilot project is part of joint research between Udayana University and the Ministry of Energy and Mineral Resources (MEMR). The RE power generation system will supply daily electricity demand in the Department of Electrical and Computer Engineering. The RE power generation system consists of a storage photovoltaic system, wind power generating units, and a diesel-powered generator set. The generated power from

this system, together with grid power will be delivered for teaching, laboratory and administration needs.

EXISTING CONDITION

The Department of Electrical and Computer Engineering (DECE) Udayana University is located in Bukit Jimbaran Campus. There are 3 allocated buildings for the department, which include DH building for teaching activities, DI building for laboratories, and DJ building for department administration. The birds-eye view of the buildings is shown in Figure 1.

Figure 1: Birds eye view of DECE Udayana University

The location of the DH Building is at 08°47'45,3" LS 115°10'26" BT. The largest energy consumption is in DH Building during day time. The roof of this building will be replaced by the concrete deck where the power generating system will be placed. The area of the concrete deck is approximately 33m x 16.5m. The PV panels and wind turbines will be installed on this deck.

In order to look at the demand characteristics, a daily load of DH building was measured and recorded. The average energy consumption is 180 kWh/day. The load profile of the DH Building is shown in Figure 2.

Figure 2: Daily energy consumption of DH Building

In addition to the load profile measurement, the potential energy from wind and solar in the campus site is also measured and recorded. Figure 3 shows the potential of solar and wind energy during the measurement period.

Figure 3: The potential wind and solar energy

RE POWER GENERATION DESIGN

The power capacity of the PV system to supply daily load can be determined by using the following equation [5]:

$$P_{PV} = \frac{E_C}{H_{sun}} * 1/\eta_{sys} \quad (1)$$

Where:

- P_{PV} = Power capacity of PV
- E_C = Total energy demand per day
- H_{sun} = Sun hour per day
- η_{sys} = System efficiency (%)

The sun hour at the location is 4.24 hours/day, and the system efficiency is 88%. The power capacity of PV then can be calculated as follows:

$$P_{PV} = \frac{180}{4.24} * \frac{1}{88\%} = 48.24 \text{ kWp} \approx 48 \text{ kWp}$$

The capacity of each module is 330 Wp with a maximum voltage of 40.1V. The required number of panel is: $48,000/330 = 145.45$ or 146 panels. Due to the lack of the deck area, and considering the shading of wind turbines, it was decided to use only 80 PV panels. The power capacity of the PV system becomes 26.4 kWp.

The maximum input voltage of the inverter is 800V, therefore the number of panels array in serial connection is:

$$J_s = \frac{V_{INV}}{V_M} = \frac{800 \text{ V}}{40.1 \text{ V}} = 19.65 \approx 20 \text{ unit}$$

There are 4-panel arrays that consist of 20 panels in serial connection, then 4 arrays are connected in parallel.

The main supply of the generating system at Udayana University is 26.4 kWp PV system, 240 kVAh battery system, 5 kWp wind turbines. The 20-kVA diesel generator set is used as a backup system. The design of the system is shown in Figure 6.

Where:

$$C_{bat} = \frac{180000}{48} * 1 * \frac{1}{80\%} = 4,688Ah$$

In addition to the PV panels, wind turbines will also be installed on the deck. The position of the wind turbines is designed by considering the high, shading, and minimum distance requirement, as shown in Figure 4. There are 10 low-speed wind turbines with a capacity of 500Wp each. The layout of the installation is shown in Figure 5.

The diagram illustrates the layout of solar panels and a fan on a flat roof. Key features include:

- Solar Panels:** Three panels are shown, each tilted at an angle of 23.5°. They are positioned on a flat roof surface.
- Fan:** A large industrial fan is located to the right of the panels, mounted on a stand that is 100 cm high from the ground and 1800 cm high from the roof level.
- Dimensions:**
 - Panel length: 3000 cm
 - Panel width: 1000 cm
 - Distance between panel bases: 2100 cm, 2000 cm, 2300 cm, 2000 cm, 2400 cm
 - Total distance from first panel base to fan base: 13800 cm
 - Roof height from ground to fan base: 1800 cm
 - Fan mounting height from roof: 100 cm
- Orientation:** The panels are oriented towards the sun, which is shown at three different times: 21/02 Juni, 21/02 Maret, and 21/02 Sept. The sun's rays are labeled "Sinar Matahari".
- Angles:** The tilt angle of the panels is 23.5°.

PV and wind turbines with the battery system are supplying DH Building. A diesel generator is operated when those components are failed. In an emergency situation, supply from the utility (PLN) will substitute the supply from the RE system. The DH building is mostly used during weekdays for lectures. During the weekend and holiday, the generating system will also supply DJ and DI Building for the lighting system. Therefore, the RE generating system will operate in off-grid or islanding mode during the weekend or holiday. The single line wiring diagram of the power supply shows in Figure 7.

Figure 7: Wiring diagram of the power supply

BENEFITS OF THE RE POWER GENERATION

The installation of the RE power generation system in the Udayana University campus obviously will give benefits not only for the teaching and research development but also for the community, government of Bali province and the government of the Republic of Indonesia. Bali has been chosen as the *National Zone for Clean Energy* (Kawasan Nasional Energi Bersih) [6]. In addition, the governor of Bali has also declared Bali as a clean and green province [7-10]. It is expected that power generation in Bali uses RE and other clean energy resources. The development of RE power generating system on campus becomes a leading pilot project in supporting the clean and green programs.

For university and research and development centers, the availability of the system will extend the opportunity for students, lecturers and researchers in the advanced exploration of the RE power generation. The system will be part of the teaching and research laboratory for energy conversion, smart control, power automation, digital measurement, and end-user management. An increased quantity and quality in RE research is expected following the installation of the power generation system.

The installation of the power generation system will also provide benefits for school students, community-based RE association and other organizations concerning RE. The system will be available for capacity building activities for community-based RE organizations. The knowledge and technical skills of the organization members can be improved by carrying out maintenance and training programs. The laboratory may also be used for RE introduction and promotions for elementary and high school students. This is particularly important to introduce RE resources as early as possible to the young generation.

SUSTAINABILITY CHALLENGES

Besides all the possible benefits, the RE power generation program also needs a lot of effort to keep its sustainability. The solar panels, wind turbines, batteries, the generator set and the inverters and control equipment require regular maintenance to assure the continuity of the generated power. Repairment has also required in case fault occurred on the equipment.

The life cycle of solar panels and wind turbines is usually designed for up to 30 years. In operating the solar panels and the wind turbines however, periodic maintenance is required. The solar panels need to be cleaned regularly to prevent sun blocking from dirt on the surface, hence reducing their efficiency. The surrounding plantation is also to be

trimmed for the same reason. The wind turbines need to be regularly lubricated to assure the rotating parts work as initially designed. Dirt is also needed to be removed to assure the efficiency of the turbines.

The batteries are usually designed for up to 2 to 3 years of operation. Batteries are a component of the system with a high investment cost. Due to a relatively short life cycle, battery changing is regularly required every 2 to 3 years.

The generator set requires fuel for operation. Fuel for diesel engines may be in a form of fossil fuel or biodiesel. A sufficient amount of fuel is required for the operation of the generator set. Besides that, regular maintenance and repair are also required for the equipment.

The inverter and control equipment mainly consist of electronic components. Although they are designed for a sufficiently long-life cycle, however; these electronics equipment is very much dependent on the surrounding environmental condition. Excessive heat due to the operation of the equipment will certainly shorten the life cycle. In contrast, the high humidity of the surrounding environment will also have a defective effect on the equipment. Unpredictable failure of this equipment may be expected.

In addition to the concern in hardware sustainability, the readiness of the university technical staff members also need to be improved. This can be achieved by providing continuous education for the staff and involvement in RE development. Support from university and government are also important not only in term of funding but also in term of policy dialog and collaboration management.

CONCLUDING REMARKS

A pilot project of RE power generation system at Udayana University has been planned with research collaboration between the university and the MEMR. The system consists of a 26.4 kWp PV system, 5 kWp wind power generators, 240 kVAh battery system, and a 20-kVA diesel generator set. The PV and wind power generator systems are placed on the roof of DH building, while the batteries and the generator set are located in a building next to DH Building. The generated power will be used for teaching, laboratory and administration needs. Commissioning of the system is planned in November 2016.

RECOMMENDATIONS

- Detailed study and analysis of resources and technology matching are needed before implementation of the RE power generation system.
- Capacity building for the technical staff members is required. The knowledge is important for the operation, maintenance and repair of the equipment.
- Support from university and government is also important for the sustainability operation of the system.

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