Development of Sustainable Power and Water Supply for Remote Areas and Disaster Response and Reconstruction in Indonesia

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Abstract—This paper presents a finalist project proposal in the Mondialogo Engineering Award 2007 that was constructed through international cooperation between two student groups from Curtin University of Technology, Australia and Gadjah Mada University, Indonesia. The project proposes a development of sustainable power and water supply, by mean of mini-grid hybrid power system with reverse osmosis desalination plant as a deferrable load, for remote areas and disaster response and reconstruction in Indonesia. As a result of recent disasters that have hit Indonesia, many people have lost their access to a reliable power and water supply. Additionally, there are many remote areas and islands that still have no appropriate electricity supply due to geographical conditions that hinder the development of an electricity grid connection because of economic reasons. This paper describes concept of system design process, intercultural dialogue between two student groups from different countries, preliminary site visits on the disaster locations in Yogyakarta, Indonesia, and previous experimental results on 5kVA mini-grid hybrid power conditioner system, a reverse osmosis desalination plant rated at 5.5 kWh/day, and the upgrading of PV arrays for Solar Water Pumping System (SPWS) rated at 375 W, all are performed at Curtin University of Technology. Through this project, students from Australia and Indonesia collaborated to participate in attaining The United Nations’ Millennium Development Goals, especially on eradicating extreme poverty and hunger, ensuring environmental sustainability, and developing a global partnership for development.

Index Terms—sustainable development, hybrid power system, renewable energy, millennium development goals.

I. INTRODUCTION

THE eradication of extreme poverty, the pledge of environmental sustainability and the development for global partnership to create a better world to live in are part of the United Nations’ Millennium Development Goals, the achievements of which are targeted to occur in 2015[1]. Some natural disasters that have crippled Indonesia, for example the Aceh Tsunami in 2004, the Yogyakarta earthquake 2006, and the Padang earthquake early this year, provided an avenue for concrete actions as part of the realisation of these goals.

This paper presents a project proposal on the development of a sustainable disaster reconstruction process to elevate the standard of life of such communities in this developing country with the aim of attaining these important objectives[2]. This project has been selected as a finalist for the Mondialogo Engineering Award 2007. The Mondialogo Engineering Award is a partnership initiated by DaimlerChrysler and UNESCO that encourages engineering students in developing and developed countries to form international teams and to create project proposals that address the United Nations’ Millennium Development Goals – especially poverty reduction and sustainable development to improve the quality of life in the developing world[3].

This project proposal has been constructed through international dialogue with student groups from Curtin University of Technology in Australia and Gadjah Mada University in Indonesia. The purpose of this project is to provide sustainable power and water supply to remote areas, especially as part of an emergency relief in Indonesia, by utilising renewable energy sources, including solar energy and wind energy, available in the particular areas. This would provide a significant improvement in the reconstruction process and thus improve the lives of the local community. It is also extremely probable that the addition of power and clean water supplies to these deprived rural areas will improve their living standards to be beyond their original conditions.

This paper describes concept of system design process, intercultural dialogue between two student groups from different countries, preliminary site visits on the disaster locations in Yogyakarta, Indonesia, and previous experimental results on 5kVA mini-grid hybrid power conditioner system, a reverse osmosis desalination plant rated at 5.5 kWh/day, and the upgrading of PV arrays for Solar Water Pumping System (SPWS) rated at 375 W, done at Curtin University of Technology[4].

II. BACKGROUND INFORMATION ON INDONESIA

A. Country Profile

Indonesia is the world’s largest archipelago consisting of over thirteen thousand islands[5]. It is located between latitudes 6 North to 11 South and longitudes 95 East to 141 East[6]. At 1,919,440 square kilometers, Indonesia is the

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world's 16th-largest country in terms of land area[7]. Service
sector is the economy's largest and accounts for 45.3% of
GDP (2005). This is followed by industry (40.7%) and
agriculture (14.0%)[8]. However, agriculture employs more
people than other sectors, accounting for 44.3% of the 95
million-strong workforce. This is followed by the services
sector (36.9%) and industry (18.8%)[9]. Major industries
include petroleum and natural gas, textiles, apparel, and
mining. Major agricultural products include palm oil, rice, tea,
coffee, spices, and rubber.

The volcanoes in Indonesia are among the most active of
the Pacific Ring of Fire. The Pacific Ring of Fire is an area of
frequent earthquakes and volcanic eruptions encircling the
basin of the Pacific Ocean. In a 40,000 km horseshoe shape, it
is associated with a nearly continuous series of oceanic
trenches, volcanic arcs, and volcanic belts and/or plate
movements[10].

Located on the equator, Indonesia has two seasons: a dry
season (June to September), influenced by the Australian
continental air masses, and a rainy season (December to
March) that is the result of mainland Asia and Pacific Ocean
air masses[11].

B. Proposed Implementation Location

The proposed implementation location is situated in the
special province of Yogyakarta. The province of Yogyakarta
is positioned on Java island of Indonesia and is the only
province in Indonesia that is still ruled by a pre-colonial
sultanate. The province of Yogyakarta bore the brunt of a 6.3-
magnitude earthquake on 27 May 2006 which killed 5,782
people and left some 36,299 persons injured. More than
135,000 houses are damaged, and 600,000 people are
homeless. The earthquake extensively damaged the local
region of Bantul, and its surrounding hinterland of Gunung
Kidul[12].

The district of Gunung Kidul, within the province of
Yogyakarta is seen to be an area that will benefit more from
the implementation of the proposed system. It is located at
110 21' east to 110 50' east and 7 46'south to 8 09'south.
The district of Gunung Kidul is classified as one of the
poorest regions in Java. One of the essential reasons is the
acute water scarcity during the months of the dry season. In
addition to the poor harvest in agriculture, the drinking water
supply is strongly impaired. As a consequence to the poor
living conditions the young and intellectual people of the
population have migrated away and thus causing the
stagnation of the region’s development. The problem of water
scarcity is made worse by the recent earthquake. However,
this district is seen to have potential renewable energy
sources, such as wind energy and solar energy, as well as lake,
with poor water hygiene, are available.

III. CONCEPT OF COOPERATION AND INTERCULTURAL
DIALOGUE

The proposal presented in this paper was developed
through international cooperation between two cross-cultural
groups with different backgrounds. Intercultural dialogue
plays a very important role in maintaining the sustainability of
the project as constant communication between the two teams
is crucial in the collaboration effort and to resolve any
problems that arise. Moreover, the involvement of the local
community is also important to ensure the success of the
project, and so that this participation will be carried out
throughout the life of the project through community
education as well as in the building and maintenance stages of
the project. So this project will provide the opportunity to
mediate a transfer of technology and knowledge to improve
the lives of the underprivileged.

Coordinating two cross-cultural groups with different
backgrounds is a challenging task and the key to success is to
ensure the cooperation is properly planned and appropriately
executed through genuine international dialogue. This
dialogue has been conducted while taking into consideration
the differences in language, ways of thinking, and culture. At
this stage of the project, communication has been mostly
conducted through electronic mail with a few important
documents sent via air mail.

The concept of cooperation and intercultural dialogue that
occurs within the project team and between the team members
and other stakeholders is illustrated in Fig. 1. As can be seen
from the diagram, two types of interaction occur among the
three groups: internal communication occurs among members
of each individual group, whereas external communication
exists between the groups. Currently, in the preliminary stage
of the project, an extensive amount of internal communication
occurs among the Curtin group to discuss mainly the design of
the hybrid system, RO plant and SWPS, and also in the
Gadjah Mada group while performing preliminary site visits
to check on the feasibility of implementation location. An
enormous amount of communication has also occurred during
the development of the project proposal.

![Fig. 1. Concept of cooperation and intercultural dialogue](image)

At this stage of the project, external communication mainly
exists between the Curtin team and the Gadjah Mada team to
discuss the system in general, as well as between the Gadjah
Mada team and the local community to extract necessary
information on the site visits. Eventually, when the project is under way, all types of communication shown in the diagram should be strongly evident among the three groups to construct a successful project.

One point that should be noted is that Fig. 1 is a simplified diagram on the concept of communication that will eventually occur in the project, and it only includes the main stakeholders of the project. There is expected to be a few NGOs, (such as CRESTA, EWB Australia, IEEE) and others (like Golden Key and World Vision) that will be involved in the project once funding is granted from Mondialogo through the MEA. Local government and local NGOs from Indonesia might also be involved in ensuring the successful implementation of the system. It is intended that these other stakeholders, and possibly some others from industry partners, will be involved to support the current project team and local community in terms of manpower and financial assistance, should the need arise.

IV. PRELIMINARY SITE VISITS

As part of devising the appropriate mini-grid hybrid power and water system, there are two main activities to undertake during the writing up of the project proposal: system design done by the Curtin group and site visits to the potential location done by the Gadjah Mada group. The Gadjah Mada group’s preliminary site visits to the disaster affected locations, mainly in Yogyakarta, were conducted concurrent with their student community services program run by the university, namely Kuliah Kerja Nyata (KKN).

In these site visits, necessary data, such as potential water sources available in the surrounding areas, geographical conditions, the infrastructure in the locations, existing local organization in the area, NGOs and local government activities, etc were obtained. Also in-depth interview with villagers, local community, as well as local government officer were done to collect some more information which will be very beneficial, so that appropriately designed approaches could be established for ensuring a sustainable engineering development by involving local communities.

V. PROPOSED SYSTEM DESIGN

The system proposed in this project is a mini-grid hybrid power system with reverse osmosis plant as a deferrable load. This is seen necessary to improve the living condition of the Gunung Kidul region and to promote renewable energy utilisation.

Design of mini-grid hybrid power system is carried out by utilising HOMER software from NREL – USA with some necessary input data, such as typical load and renewable energy resources available in the particular remote area, deferrable load (reverse osmosis desalination plant), inverter, renewable energy generator (wind turbine, solar PV), battery, diesel generator, project lifetime, initial cost, interest rate, etc[13]. The detail of the design processes for mini-grid hybrid power system for remote area can be found in the paper written by the authors, which was published and presented in the First HOMER Webcast and available online.
through NREL website[14]. The overall configuration of the mini-grid hybrid power system with reverse osmosis plant as a deferrable load is shown in Fig. 5 as the result of HOMER simulation.

Fig. 5. Mini-grid hybrid power and water system configuration

The Curtin group also has managed to build and test performance on a prototype 5 kVA mini-grid hybrid power systems and a reverse osmosis desalination plant rated at 5.5 kWh/day. As an addition to those two experimental works mentioned above, the Curtin group also conducted tests and experiments on the upgrading of PV arrays for Solar Water Pumping System (SWPS) installed in Curtin University of Technology. From these activities, the Curtin group gained much information and hands-on experiences on that particular system, and therefore it will be very beneficial for supporting the project proposal.

A. Mini-grid Hybrid Power System

In the Curtin group, there currently exists an on-going research project on mini-grid hybrid power system and reverse osmosis plant by utilizing renewable energy technology, mainly as part of doctoral research projects. The AC coupling mini-grid hybrid power system configuration is shown in Fig. 6.

Fig. 6. AC-Coupling mini-grid hybrid power system

In Fig. 7, it is shown the equivalent circuit diagram of the hybrid system where the bi-directional inverter is operated in parallel with the diesel generator to supply the load. As depicted in Fig. 8, during low load period power demand is supplied by inverting the energy from the battery bank through VCVSI (Voltage-Controlled VSI) mode to provide a certain level of voltage and frequency output. When the load increases and the inverter is not capable to provide the supply of power any longer, the diesel generator is operated to cover the load demand and the excess of the energy is used to charge the battery in CCVSI (Current-Controlled VSI) mode. The overall system test facility is presented in Fig. 9.

Fig. 7. Equivalent circuit diagram of hybrid system

Fig. 8. Energy management in hybrid system

Fig. 9. Photograph of mini-grid hybrid system test facility

B. Reverse Osmosis Desalination Plant

In order to provide consumable water supply, a reverse osmosis desalination plant is installed as a deferrable load. In the proposed implementation location of Gunung Kidul, there are some non-exhaustible water sources and are capable of supplying water all year round. However, the water of this source has greenish water that worsens during the dry season. Moreover, to add to the water quality problem, these water sources are used by the locals to shower, wash clothes and livestock. Due to the severity of the quality problem, these sources are unfit to be used as drinking water source. This is a potential input to the RO system, which will be desalinated
and make it fit for human consumption.

The laboratory scale of RO plant rated at 5.51 kWh/day has been built and tested in Curtin University of Technology. The configuration of the system and photograph of the test bed for the plant are shown in Fig. 10 and Fig. 11, respectively.

Fig. 10. Reverse osmosis desalination plant configuration

Control aspects of the mini-grid hybrid power and water supply system also have been dealt with carefully by utilizing the PLC-SCADA system, and recently it was presented in the International Symposium of Power Electronics for Distributed Generation hosted by IEEE Power Electronics Society, which was held in Hefei, China[15]. An image of SCADA/HMI for the Reverse Osmosis Desalination Plant test from the PC monitor can be seen in Fig. 12.

Fig. 11. Test bed of the RO Plant

C. Solar Water Pumping System

Test and upgrading of PV arrays on the existing solar water pumping system (SWPS) prototype installed in Curtin University of Technology, which can be co-operated in the implemented system as part of the load that will be supplied by the power system, has been done thoroughly and the possible upward and downward scaling on the system has been considered.

There were eight old PV modules to be replaced with the new ones, and to do so the Curtin group conducted test and experiment on the performance of the PV arrays connected with the water pumping system. Test were done to obtain some data for example Open Circuit Voltage (Vpv_OC) and Short Circuit Current (Ipv_SC) of the PV Array, Maximum Voltage and Current (Vmppt and Imppt) of the power conditioner or Maximum Power Point Tracker (MPPT). Performing test on the configuration of PV Array, which is constructed from series and parallel connection of PV modules, is also necessary to find the optimum output in order to power 375 W water pump. A photograph of testing on the SWPS installed at Curtin University of Technology is presented in Fig. 13.

Fig. 12. SCADA image of RO test system

VI. PROJECT TIME LINE

The project timeline is planned as shown in the following Table I. This is an indicative timeline that has been carefully prepared taking into consideration many foreseen and unforeseen circumstances. This timeline is a simplified version and consists of 3 stages: preparation, system building, and system testing and deployment, which in turn comprises of many elements.

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VII. CONCLUSIONS

The design process on mini-grid hybrid power and water supply system, concept of intercultural dialogue between two international student groups Australia – Indonesia, experimental results on the mini-grid hybrid power conditioner, reverse osmosis plant and solar water pumping system, and preliminary site visits from the disaster affected location in Indonesia were discussed in this paper. With appropriate approach on the technical, environmental, economical and social issues, this project aims to propose a development of sustainable power and water supply for remote areas and disaster response and reconstruction.

Through the Mondialogo Engineering Award 2007, two groups of dedicated students from Australia and Indonesia, have been given the opportunity to prepare a proposal to improve the lives of the less privileged remote community who are also suffering from the natural disaster in Yogyakarta, Indonesia. It is believed that, through this small project, some improvements can gradually flow through to this community and eventually other communities with similar conditions.

VIII. ACKNOWLEDGEMENTS

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IX. REFERENCES