RURAL ELECTRIFICATION IN INDONESIA with Emphasis on Microhydro Electric Scheme: A Challenge to Implement More Appropriate Research Methods

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1. Introduction

The Republic of Indonesia, stretching between mainland Southeast Asia and the north coast of Australia and lying within the tropical monsoon region, is the largest archipelagic nation. Situated where the Pacific and Indian oceans meet, having the world's fifth largest population and endowed with extensive and varied natural resources, Indonesia has the potential to become a great and prosperous power.

Indonesia is one of the more densely populated rural countries in the world in its settled areas and the poverty of its rural residents is among the worst. Most farmers (especially in Java) live on less than a hectare of land and must supplement their incomes with laboring jobs.

An accelerated rural economic growth would contribute much to the development of Indonesia's national economy. Rural development has always been the ultimate goal of the Indonesian Government because of the beneficial effect on social and cultural life.

Energy is one of the determining factors in economic development. It has played an important function in Indonesia's development during the past and will undoubtedly assume an increasing role in the years to come. It has not so far constituted a constraint because of Indonesia's large potential energy resources and relatively small utilization at the present stage of development.

In the 21st century, everyone will face new challenges posed by the technological revolution that is changing the rule of business. The combined power of telecommunications and computer technology is creating relatively inexpensive, global networks that transfer voice messages, text, graphics, video, and data within seconds. These sophisticated technologies create new type of products, including educational products. Changes in technology can also create whole new ways of life.

The rapid change in various aspect of life for the past decade are triggering the challenge towards educational system in order to meet the needs of the evolving environment that also struggling to satisfy the needs of humankind. The Ministry of National Education of the Republic of Indonesia has implemented strategic planning for 2005 to 2009, namely, equal opportunity and extension of access for education; enhancement of quality, relevance, and competitiveness of education outcomes; and empowerment of governance, accountability, image of public educations. One of the efforts is to build a national wide area networks, JARDIKNAS (*Jaringan Pendidikan Nasional* – National Education Networks), consisting of four network zone:

1. **Office Zone**: of official offices and institutions to disseminate on-line data and management of educational information systems.
2. **Indonesian Higher Education Network**: emphasizing on research and the advancement of science, technology, and arts.
3. **School Net**: information access and e-learning among primary and secondary schools.
4. **Personal Zone**: enabling teachers and students to access information and e-learning.

The Networks have been operational since 2006 and consisting of 24 747 nodes in 33 provinces throughout Indonesia. Implementation of information and communication technologies

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such as radio, television, computers, and the emergence of the Internet have proven to be sufficient tools to minimize the gap between urban and rural residents.

The program will not be thoroughly successful without the availability of electricity, especially in rural areas where the targets of development mostly live.

2. Rural Electrificatiom

Because of the diminishing supplies of biomass energy, traditionally used in most rural areas, and the high cost of kerosene, population growth and deforestation endanger the ecosystem which supports village life.

Rural electrification in developing countries is intended to serve both economic and social aims. It is often regarded as synonymous with rural development, and usually accorded a prominent place in the plans of developing countries.

Whether or not rural electrification is economically justifiable, the Government has made it clear that there is a commitment to commencing the task of rural electrification. Other conditions also exist that make such a program urgent. The rural residents have high expectations and are clamoring for action by the government. Assuming that for social and political reasons there will be an increasing emphasis on rural electrification in Indonesia, the question then is how the benefits from such a program might be maximized.

The main choices for rural electrification appear to be between the extension of the main grid system and the installation of small scattered plants. Rural electric systems in developing countries are especially vulnerable to technical problems. It is therefore imperative to introduce systems that are reliable, low cost, low maintenance, and simple.

It has long been claimed that rural electrification greatly improves the quality of life. Lighting alone brings benefits such as increased study time and improved study environment for school children, extended hours for small businesses, and greater security. But electrification brings more than light. Its second most common use is for television, which brings both entertainment and information. Last but least, education will be benefitted most by the availability of electric power, as mentioned above. The people who live in rural areas greatly appreciate these benefits and are willing to pay for them at levels more than sufficient to cover the costs. However, the evaluation of these and other benefits (for example, in terms of public goods), as well as of their distribution, has been sparse.

Rural electrification usually passes through four stages, all of which can be found in Indonesia and various other Asian countries. In the first stage, a few scattered businesses install their own small generators exclusively for their own use. From the user's point of view, this is often a relatively satisfactory way of getting electricity, although somewhat expensive one. However, from the national point of view, this is very wasteful because often capacity of utilization is low and costs per kWh supplied are high.

In the second stage, factories, plantations, or perhaps local government authorities take it upon themselves to sell small amounts of electricity to nearby consumers after a small collective demand develops in rural area. Alternatively, a small generating plant can be installed as part of the official rural electrification scheme. In this system, electricity is often available only during specified hours of the day or evening.

In the third stage, the centers of collective demand served in the second phase by isolated generators are connected into the main grid network. In the final stage, areas of low demand surrounding the already electrified 'islands' are connected into the main network.

Experience from other developing nations suggests that six main types of problems are likely to arise: technical difficulties, quality of service, administration, level of demand, high costs, and the financing programs. These problems are interrelated, so a failure in any one area can be sufficient to endanger the success of a rural electrification program.

The Indonesian Government aims to increase use of new and renewable resources to produce energy. Indonesia has abundant of potential renewable energy resources, potential supplies of geothermal, solar, wind, microhydro, and biomass energy are estimated of 160 gigawatts of electric capacity. The development of renewable energy has been slow due to the technology involved in harnessing these resources are more expensive than the energy produced by conventional technology for fossil fuel power plants. National Research Board of Indonesia has put development and utilization of new and renewable energy resources into its agenda. The Blue Print of Research, Development, and Implementation on New and Renewable Energy Resources issued by the Ministry of Research and Technology of the Republic of Indonesia targeted that renewable energy contributes 4% of the country's electricity demand by 2025. By 2003 it contributes 1.43%.

Along with the extension of national grid, two renewable energy resources commonly found for rural electrification: solar energy and microhydro. Photovoltaic solar energy is used in rural area households. The potential of solar energy ini Indonesia is about 4.8 $kWh/m^2/day$. Some projects of solar home system have been implemented in some provinces in Indonesia with the installed capacity of about 0.008 GW by 2005.

Microhydro scheme, where the resources are available, also widely used in remote areas and, in Indonesia, 0.084 GW has been installed out of the potential of 0.46 GW by 2005. Integrated Micro-hydro Development and Application Programme (IMIDAP) is one of projects run by the Directorate General of Electricity and Energy Utilization together with United Nations Development Programme aimed to expand Indonesia's energy options through the promotion of microhydro technology. It will further contribute to poverty eradication by ensuring higher productivity for rural communities through more reliable and ready energy sources.

Non-government organizations play an important role in Indonesia's energy sector, mainly as advisers, project developers and managers, in executing some energy programmes. They are also active in the different new and renewable energy sources.

3. Microhydro Electric Schemes

Water energy is the only renewable energy source already exploited by man on a large scale with a well-developed technological base to support its continued exploitation. Hydropower is a form of non-depleting, self-replenishing energy. Given good initial design, the facilities for exploiting it require minimum maintenance; and hence offer the potential for cheap energy supply. In most cases it is also the most efficient and least polluting form of power.

Among the limiting factors of hydropower are high initial investment and long construction time, as well as the fact that the favorable sites are usually situated in remote areas away from

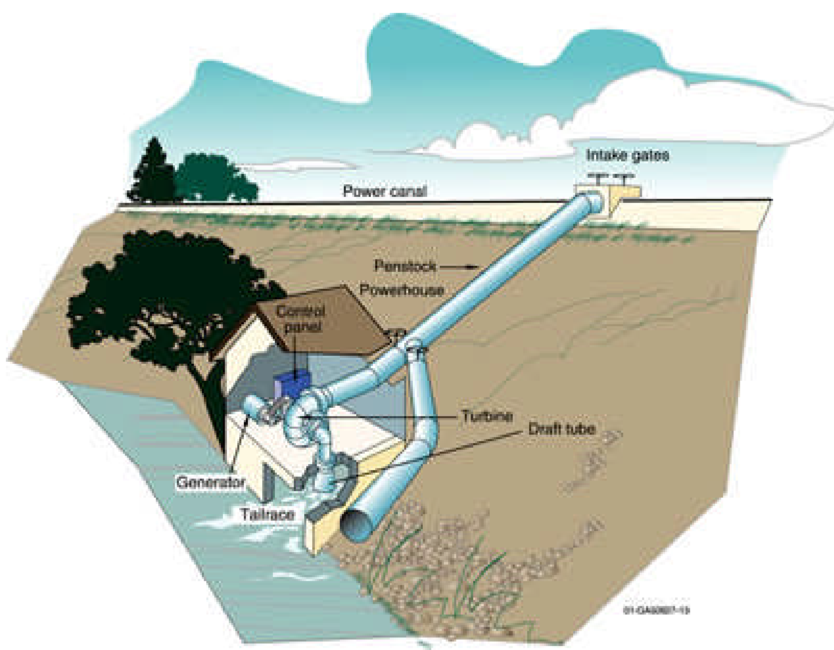

Figure 1 Microhydro scheme
www.geni.org

energy-consuming centers. Developing countries are increasingly taking up hydro surveys and feasibility studies in order to quantify these competing factors.

Remote, isolated regions of many developing countries including Indonesia, far removed from the national grid, must often rely on expensive fossil fuel power generation. But, in areas with substantial water resources, hydropower has proven to be a much more economical source of power. Small hydropower plant can provide mechanical power to small industries or electrical power to run enterprises and electrify homes in rural areas, whereby alleviating some of the drudgery, helping to generate income, displacing wood or kerosene, and improving the quality of life of a large segment of the population. A typical microhydro scheme is shown in Figure 1.

According to international – though not fully standardized – definitions, hydroelectric power plants can be classified according to size as follows:

- Large hydro plants > 100 MW
- Medium hydro plant 15 – 100 MW
- Small hydro plant 1 – 15 MW
- Minihydro plant 100 kW – 1 MW
- Microhydro plant up to 100 kW

Microhydro plants have been in use in many countries such as France, Peru, Chine, Nepal, Solomon Islands, and Indonesia.

Microhydro plant can be built at relatively low cost by using indigenous materials as far as possible. The cost of turbine and generator can be reduced by standardizing the sizes and other specification of the machinery.

If these plants are located in the vicinity of existing grid, they can be connected to the grid. They can be more effectively used to replace energy supplied by fossil fuel as well as to provide additional capacity. Electrical Energy Act of the Republic of Indonesia, Number 10, 2002 allows small private developers to offer their excess electricity to PLN (Perusahaan Listrik Negara – State Electric Company).

There are several advantages and disadvantages of microhydro plant compared with diesel plant of the same size,

- Investment costs of a microhydro plant are higher that the investment costs of a diesel plant.
- After about three years, the sum of the investment and running costs of a microhydro

Figure 2 Kalijari checkdam for Mount Kelud

Figure 3 Brawijaya University Microhydro Field Laboratory at Kalijari

plant are smaller than those of a diesel plant.

- The use of the microhydro plant is limited to the availability of water resources, which is often distant from the demand center.
- Installation time for a diesel plant is much shorter than that of a microhydro plant.
- The life expectancy of a microhydro plant is much longer that that of a diesel plant (betweet 20 to 40 years compared to perhaps 5 years).
- A microhydro plant is easier to maintain and operate and requires fewer skilled workers than a comparable diesel plant.

Microhydro schemes can be build in conjunction with irrigation systems or as part of check dams can be found in Java. A scheme in Kalijari, Blitar, East Java is a good example and while supplying electric power to about 60 homes in nearby hamlet, it is also used as a field laboratory of Brawijaya University, as shown in Figure 2 and Figure 3.

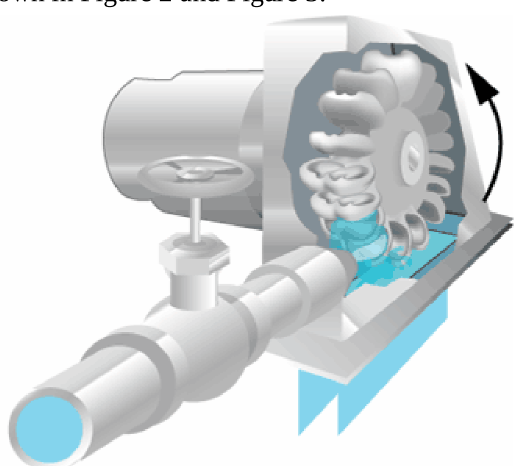

Figure 4 Pelton wheel
www.energyalternatives.ca

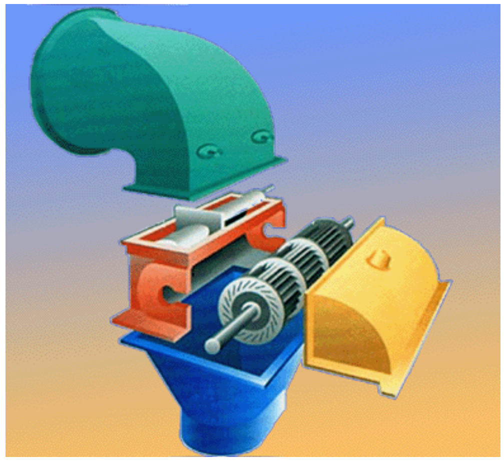

Figure 5 Cross-flow turbine
members.tripod.com

It should be noted that the required equipment for the manufacturing of microhydro turbines is generally found in existing factories or workshops in Indonesia. The construction of a water turbine is not as complicated as that of other prime movers. The construction requirements are relatively simple: working rpm and temperature are low so it does not need high quality material and the precision is not necessarily high.

There are two principal alternative designs of turbines that are viable for microhydro plants: Pelton wheel and cross-flow turbine, as shown in Figure 4 and Figure 5 respectively. The Pelton wheel has been successfully used in plants ranging to as low as 5 kW, given the combination of high head and low flow rate necessary for Pelton operation. For local manufacturer, a small foundry is required, with simple workshop facilities in fitting, turning, and welding.

In many areas with low head, the cross-flow turbine offers a simple alternative. Although the cross-flow turbine may take second place to the Pelton wheel in terms of weight, size, and material cost, it is surpassed in constructional simplicity. Many microhydro schemes in East Java utilize the locally made cross-flow turbines.

The significant difference between microhydro plants and the larger hydro plants is the method of regulation. Up until recently, both large and small scale hydro systems have been controlled by flow regulation, whereby increased demand from the load is met by increasing the flow through the turbine to keep the turbine speed constant. This type of governing requires expensive and complicated mechanical equipment which can only be justified economically when the total amount of power produced is large. Moreover, technical specifications in response times and percentage load variations for very small systems are more demanding than for larger ones.

Electronic load controller offers a viable solution for microhydro systems. With this type of governor, the turbine is operated at constant flow and the total load on the generator is maintained at a constant value. Surplus power is shunted to dummy loads whenever it is not required for the primary loads. The dummy loads can be heating elements, battery chargers, or motor to pump water. The technology involved in electronic controllers is quite sophisticated but their robustness and reliability allow then to be used in microhydro schemes in developing ountries such as Indonesia. This type of governor is ‘water wasting’ in the sense that water is always released at a rate capable of supplying the maximum primary load. However, the only alternative to this approach is to build a flowregulating equipment which would cost prohibitively high for a microhydro installation.

Traditionally, brushless alternators have been used for a stand-alone mcrohydro systems. Generator of this type have been widely used since they do not need external excitation and thus they permit lengthy unattended running time. Alternators designed for small diesel gen-set used extensively in microhydro schemes in Indonesia. In this case, since they are designed to run 1500 rpm, gear box systems are required to increase the speed of the water turbines.

Inductions generators have not had widespread practical use as generators. They have received relatively little attention in the literature, particularly when operating in the self-excited mode, rather being in parallel with a grid when they obtain their exciting reactive power from the mains supply. The reason is that, until recently, it has been difficult to control the voltage and frequency of self-excited induction generators. However, the recent development of static var sources wih power electronic controls, combined with the depletion of non-renewable energy resources, has brought increased interest in the subject.

For microhydro electric schemes, stand-alone self-excited induction generators offer significant cost reductions in the system initial costs and may be advantageous compared with alternators due to the ruggedness and low maintenance requirements of induction machines.

Induction generator in this case is simply an induction motor, that widely available, driven faster than their synchronous speed, causing them to generate power. It is also well known that induction motor will operate as generator if supply of reactive power is available to provide the machine's excitation. Self excitation can be achieved by the connection of appropriate capacitors across the motor's terminal allowing the motor to be used as an isolated generator. Practical application of induction generators may be limited unless reliable, cost-effective means of voltage and frequency controls are available. Thus it calls for further study and research to be conducted.

4. Problems of Microhydro Schemes

Problems of rural electrication, technical difficulties, quality of service, administration, level of demand, high costs, and the financing programs also arise in the development of microhydro schemes.

Stakeholders' involvement is often neglected during project selection, planning, and implementation. This could endanger project acceptance and sense of belonging of the community, making the lifetime of the project shorter.

Technical problems could arise from poor design and construction quality. Plant operation often done with no proper standard operating procedure and maintenance is often neglected. The result is voltage fluctuation and frequent power outages, and lower the quality of service. Administration problems appear to be most common due the awareness of proper organization often lacking in rural areas.

There is a need for adoption of proper technical standards for equipment, methods, and practices. Uniform practices should be adopted. However, while it was important to maintain high standards for establishment of microhydro schemes, it will probably necessary to reduce the standards to some extent in order to effect savings in the capital outlay. This reduction in standards should not be at the expense of general safety. Some standards for rural electrification have been issued by Perusahaan Listrik Negara.

The realizations of industrial potentials and agricultural development are closely related to the success of rural electrification programs. The rural loads are scattered. The demand per consumer is small, owing to the low standard of living, and it is difficult to supply power at economic rates for such small scattered loads. The problem, in fact, offers a challenge and an opportunity to the engineers and administrators of the microhydro schemes. A satisfactory solution will depend upon the ingenuity and professional skill they will bring to bear upon it, and on the cooperation they scure from research institutions, manufacturers, and distributors of agricultural equipment and domestic appliances, and from the consumers.

5. Conclusion

Rural electrification can be defined as the task of providing a country's rural population with the electric power necessary to meet its needs. However, this simple definition should not mask the financial, technical, and social complexity of the task.

Rural electrification can provide one of the most effective means of alleviating poverty in rural areas, providing better quality of life through light, security, information, and education, as well as saving the ecosystem. Among the productive uses of electricity in rural areas are processing agricultural produce, cold storage and preservation of food, and small-scale industry such as weaving, tailoring, etc. This does not mean that the use of electricity for domestic purposes is unimportant, but it should not be pursued as the primary objective.

Microhydro electric system is evolving, particularly in relation to the motivation of project developers. Recently, the majority of initial installations might be said to be the result of a technological push, plants were installed to test their technical viability and their acceptability. This experience has established the technical reliability of the microhydro systems, reduced their costs and resulted in substantial technical improvement. Microhydro systems have greatly improved by electronic load controllers, low cost turbine designs, the use of electric motors as generators, and the use of plastics in pipe work and penstocks. However, more research still be needed to improve what are achieved today.

Rural electrification is more than technical problem, acceptability of the power, utilization of electricity will still need to be evaluated and studied in order to achieve the goal of alleviating poverty. Social and financial aspects of rural electrification should also be seriously considered.

A new approach to rural electrification is required, that it should be economically feasible and equitable, environmentally sustainable, institutionally and technologically diverse, with greater roles for the private sector and local communities, and adapted to the low levels of rural electricity demand.

The author has high hope that the First International Workshop on Modern Research Methods will enlighten to the matter.

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