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Hybrid Power Generator Model to Rural Electrification

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Abstract. This paper presents the hybrid power generator model to demonstrate the feasibility of an alternative method for rural electrification, especially in geographically hard-to-reach areas. The hybrid power generator offers a distributed low-power low-voltage DC residential electricity rather than the legacy centralized relatively high-power high-voltage AC system. The hybrid power generator directly runs DC loads; thus, bypassing losses associated with the traditional AC voltage system. The hybrid power generator is an individual or family-based approach to rural electrification. This in turn yields to an alternative solution that is scalable, affordable, and flexible. The hybrid power generator may also utilize human-powered energy sources, making it even more sustainable in producing off-grid electricity. The hybrid power generator has been designed to allow a maximum capacity of 900W provided by as many as three renewable energy sources such as solar, wind, and hydro sources. Plans to enhance the hybrid power generator model and for its field testing to further demonstrate its feasibility for adopting the technology will also be summarized.

INTRODUCTION

To this day, the primary energy sources for the world come from fossil fuels such as petroleum, coal, and natural gas. These energy sources have been known to cause problems mainly in the areas of sustainability and national security. Furthermore, based on the results of many studies, fossil fuel consumption is a major cause of global warming which is a phenomenon where greenhouse gases produced from burning fossil fuels such as petroleum and coal warm the earth. This has been known to cause negative environmental effects which affect human and non-human life on earth. This provides the motivation to seek for alternative energy sources such as renewable energy sources which do not emit green-house gases.

Renewable energy sources have the potential to provide long-lasting solutions to the aforementioned problems. It is for this very reason many countries in the world have invested in renewable energy to provide an alternative source of energy. Renewable energy sources have also been utilized in many third world countries for rural electrification such as in Latin America [1], Bangladesh [2], Lao [3], and Indonesia [4]. This makes sense since renewable resources are abundant, locally available, and are fairly evenly distributed around the earth. Even small amounts of energy can make a significant difference in remote rural areas and hence higher costs are justifiable. Furthermore, utilization of locally available renewable resources can create job opportunities and mitigate the trend to mass movement to urban areas.

In recent years there have been intensive efforts to utilize DC in distribution system to supplement the traditionally used AC system. Examples are DC system used in microgrid with renewable energy sources [5], [6], data centers [7], and electric vehicle charging stations [8]. For residential electricity DC system has also been studied as part of the DC microgrid system [9], [10], [11]; hence, the voltage level is still relatively high. For small houses as typically found in rural areas of many third world countries, the use of low voltage system for direct interface or connection to small-scale renewable energy source may offer more benefits than the high-voltage counterpart. The Hybrid Power Generator project aims to develop a low-voltage DC electrical system for a single small house mainly to help in rural electrification effort.

DC ELECTRICAL SYSTEM

One primary weakness of renewable energy sources is that their operation is not guaranteed based on many things such as weather conditions (with the exception of some such as geothermal). Therefore, they may not be practical if used as the sole energy source for a house. However, this problem may be resolved using a Hybrid Power Generator that would integrate multiple renewable energy sources, batteries and DC loads, all into one residential DC system.

Additionally because photovoltaic natively outputs DC power at relatively low voltage, they must be connected to an inverter to produce a relatively high AC voltage so the energy can be useful to a traditional AC house. This conversion introduces losses that are estimated to be between 23% and 28% [12]. This AC power when used for residential loads are mostly converted back to DC through rectification process inside each load. This further adds conversion losses between 17% and 35%. The use of DC electrical system can help eliminate the wasteful conversion of AC to DC, and in many cases DC to AC prior to entering the house. With the DC system, it has been estimated that more than overall 15% efficiency improvement may be obtained as compared to its AC system counterpart.

Another problem with the use of inverter is its lifetime due to electrolytic capacitors that are heavily used in inverters. These capacitors are notorious for a short lifespan, typically 5 to 8 years. This necessitates the implementation of maintenance plans that can be costly and will require power shutdown during replacements. With DC system, the heavy reliant on electrolytic capacitor bank may be avoided, thus making residential electrical system more efficient, reliable and economical to operate.

The Hybrid Power Generator allows multiple renewable energy sources for its source of electricity. To help minimize the issue with intermittency of renewable energy sources, the Hybrid Power Generator can also take in energy from human-powered generators. Figure 1 illustrates the system diagram of a Hybrid Power Generator.

The Hybrid Power Generator is an individual or family-based approach to rural electrification allowing people in rural areas. This makes the DC system scalable and flexible in power level. For example, most families in these hard-to-reach areas are poor, so they can start using electricity in a smallest possible way based on what they need the most. For lighting as an example, a portable DC light bulb that is rechargeable by using the sunlight may be a good start.

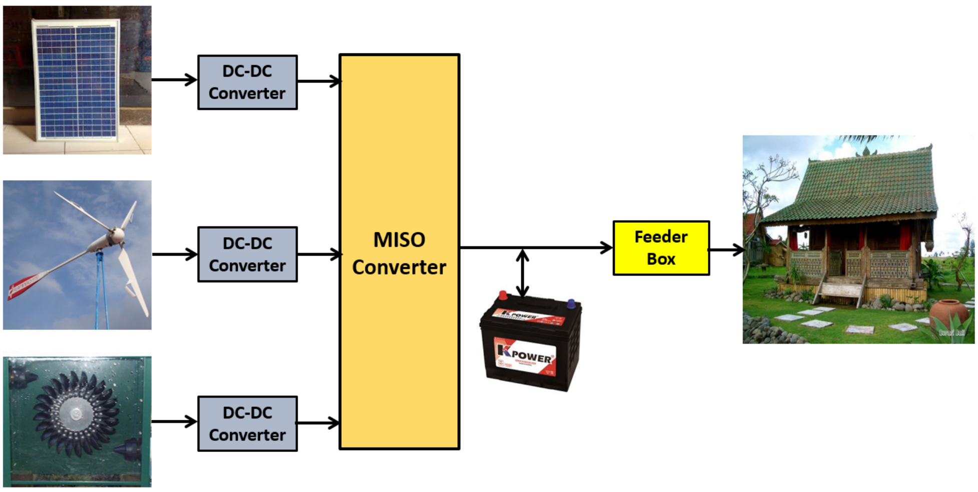

FIGURE 1. Overall simplified block diagram of the Hybrid Power Generator

HYBRID POWER GENERATOR COMPONENTS

Energy Sources

Referring to Figure 1, the Hybrid Power Generator may incorporate multiple energy sources, mainly from renewables. Renewable energy for power generation is not new; however, low-power renewable energy source for use in small-scale residential system is unique. For example, due to the low-power requirement of a Hybrid Power Generator, it is now crucial to be able to harvest energy from common small water streams that are currently not being utilized for hydropower generation. This brought up the idea of portable nano-hydro power generator which takes advantage of small water streams to charge a battery for later use in the Hybrid Power Generator. Another source of electricity for the Hybrid Power Generator is the human-powered generator. This method makes use of human power to generate electricity such as the bicycle generator. The main reason for having such a source is to complement the renewable energy sources that are intermittent, and to promote fun and healthy activities for family while at the same time generate electricity for the house. Realizing that a family in rural areas of third world countries typically have several children, play park power generator may be ideal since they provide a simple and cheap way of generating electricity. Merry-go-round, and swing generators are examples of play-park generator components.

MISO Converter

Another component of the Hybrid Power Generator is the Multiple Input Single Output (MISO) Converter which allows the use of multiple energy sources to ensure continuous supply of energy to a DC bus.

Distribution

The Hybrid Power Generator is designed to allow easy adoptability in its implementation. If a house has been constructed to operate with AC system, then transforming to DC should be a relatively easy transition. In particular, the move to the DC system should incorporate the use of the same AC wiring system and lighting fixtures. This not only minimizes the cost of implementing DC system, but also promotes sustainability by reusing common AC house electrical components.

As shown in Figure 2, a DC distribution system serves the simple purpose of delivering power from energy sources through the MISO Converter to a set of loads that will in total accumulate to approximately 600 to 900 Watts. The MISO converter takes in more inputs from energy sources at different voltage levels and produces one DC output voltage which has been established to be 48 VDC. A Hybrid Power Generator must be designed to fulfill the needs that a typical home provides. The Hybrid Power Generator should have the ability to provide for example indoor and outdoor lighting at minimum, floor fan, tv, laptop, refrigerator, and many other services.

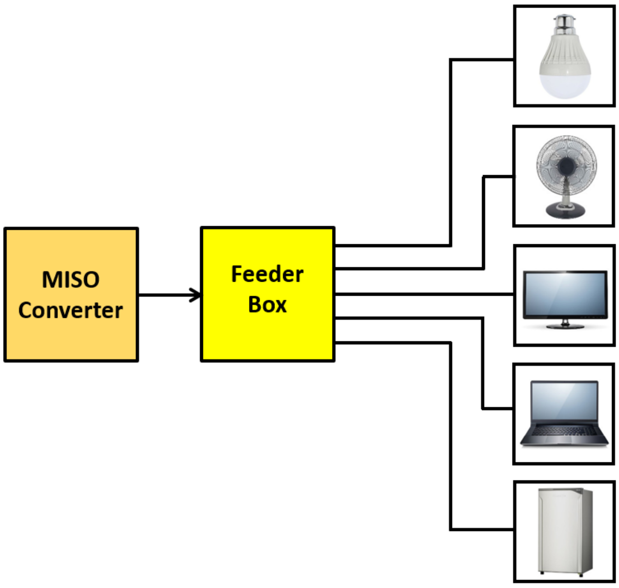

FIGURE 2. Hybrid Power Generator distribution

Loads

Finally, at the end of the DC distribution system are the DC loads. For rural areas the main residential load is predominantly lighting. Due to advances in LED technology, it is now possible to have DC light bulbs that are energy efficient and low-cost. Additionally, the house will also provide USB plugs to allow charging of portable electronics such as cell phones, laptop, etc.

CONCLUSIONS

The Hybrid Power Generator model with the description of its main components is presented in this paper. The research project is a humanitarian effort aimed to provide access to electricity in rural areas while promoting the use of renewable energy sources. The project has long and short term goals with a working prototype planned to be completed by the end of 2018. The prototype will be the first of its kind in Indonesia and will serve as a demonstration site of the Hybrid Power Generator technology.

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