Toward the sustainable operation and management of micro-hydropower generation in a traditional community of Indonesia

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Micro-hydropower (MHP) generation is one of the most introduced renewable energies in Indonesia but much of the MHP plants introduced in the remote rural areas have stopped, the causes of which remained unclear. This study aimed to clarify the operational status of MHP plants managed mainly by residents in a remote village, Ciptagelar, and explore how to resolve the problems related to the MHP operations. For this, we conducted hearing investigation and hydrological observations in the village. This paper introduced our efforts toward realizing the sustainable operation and management of the MHP generation in the remote village, through the flood simulation and the development of remote observation tools.
Key words: Off-grid power, Sustainable development, Transdisciplinary research

1. INTRODUCTION

World energy demand has been increasing with population and economic growth, especially in the developing countries. It is predicted that developing countries will account for almost 60% of the world coal-based electricity in 2030[1] and Asia's share of world primary energy consumption will increase to 46% in 2040[2]. Continued large dependance on finite fossil fuels will make it very difficult to sustain energy supply to satisfy the world demand. On the other hand, the energy supply is needed for eliminating poverty and constructing a resilient society. Promoting the use of renewable energies is one of the best ways to solve the dilemma between the increasing energy demand and the finite energy resources.

Indonesia has many remote rural areas that are not connected to the government-owned power grid because it is the world's largest archipelago state, which consists of more than 17 000 islands, with complex terrain. On the other hand, in recent years, its economy growth and subsequently energy demand has been rapidly increasing, resulting in the economic disparity between rural and urbanized areas.

Indonesian government has promoted rural electrification by renewable energies to reduce the economic disparity between remote and urbanized areas. Micro-hydropower (MHP) generation is one of the most introduced renewable energies in Indonesia[3] because Indonesia has steep terrain and thereby has enormous MHP potential and because the MHP plant does not need massive constructions, such as dams. On the other hand, it has been reported that much of the MHP plants introduced in remote rural areas stopped due to some failures[4]. However, no follow-up survey of operations or maintenance of MHP plants has been reported after their introduction to the remote villages and therefore their operational status remains unclear. In this study, we aimed to clarify the operational status of MHP plants managed mainly by residents in the remote village and explore how to resolve the problems related to the MHP operations. For this, we investigated the history of the MHP project and the operational status of the MHP plants and conducted hydrological observations in Ciptagelar village located in the mountainous area of West Java. Then we tried to conduct flood simulation and develop some observation tools for preventing the MHP plants from stopping.

2. MATERIALS AND METHODS

2.1 Site description

The study site is Ciptagelar village located in the mountainous area of Sukabumi District, West Java Province, Indonesia (6°48'S, 106°30'E; 1122 m a.s.l.). This village is the heart of the Sundanese ethnic group, Kasepuhan adat community. Approximately 300 people with 130 households live their traditional lives in the village. The main industry is rice farming and thus monetary incomes of the village are low.

Power supply from the Indonesian government-owned power company to the village has been restricted because the village is located along the boundary of Gunung Halimun National Park with steep terrain and unpaved roads, which results in the limited accessibility to the village. Thus, four MHP plants have been installed in a sequential order since 1997 with the aid of external donors, e.g., local government, NGOs, and local bank, to electrify the village under the leader of the community. Detailed descriptions for the village and the four MHP plants are presented in Sato and Ide[4], Sato et al.[5], and Isa et al.[6]

2.2 Hearing investigation and hydrological observations

To understand the history of the MHP project, along with the outline, operation, and maintenance of the MHP plants in Ciptagelar village, we interviewed the operator and the chief administrator of the plants during 2016 to 2018. Additionally, we read the book regarding electricity charges collected from residents and staff costs for the operation and maintenance of the plants.

Hydrological observations were conducted from October 2016 to October 2019. Rainfall and water levels of the intake river were recorded at hourly intervals using a tipping bucket rain gauge (RG3-M, Onset Computer Corp.) and a pressure sensor (U20L, Onset Computer Corp.), respectively. The actual water level and river runoff were measured by a metal measure and a propeller meter (VR-301V, KENEK Corp.), respectively, and then a relationship between the water level and river runoff was developed to estimate runoff data during the observation period based on water levels obtained by the pressure sensor.

3. RESULTS AND DISCUSSION

3.1 Current status of MHP plants

Results of the hearing investigation revealed that four MHP plants in Ciptagelar village were frequently damaged and broken because of human errors and natural disasters, such as heavy rainfall. Especially, large floods sometimes broke the intake weir and stopped the MHP generation for a long time, e.g., seven months. On the other hand, output of the MHP plants estimated from flow regimes of the intake river indicated that the electricity supply could barely cover the electricity demand during low flow periods[5]. This suggests that insufficient management of the intake easily makes the output of the MHP plant low during the dry periods, resulting in the blackout because litter and garbage sometimes block the intake and stop the water flow into the plant. Our calculation of the MHP operation and maintenance costs and data related to electricity charges revealed that electricity fees collected from residents can barely cover standard maintenance costs (Fig. 1) but are insufficient to allay disaster costs[5]. Additionally, no accomplished technician was available for repairing damaged or broken MHP plants.

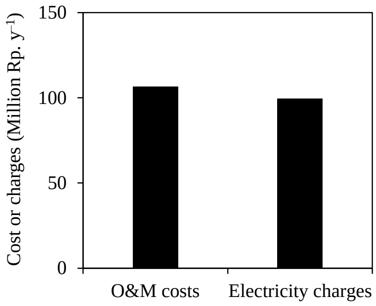

Fig. 1 Operation and maintenance (O&M) costs of the MHP plants and electricity charges collected from residents during 2017.

3.2 Efforts toward the sustainable operation and management of MHP plants

To prevent the MHP plants from being damaged or broken by natural disaster, they need some reinforcement based on hydrological phenomena. Moreover, to prevent the MHP generation from stopping during the dry periods due to the imbalance between the electricity supply and demand, the monitoring of the electricity demand and the intake are needed. To achieve these, we conducted flood simulation and tried to develop remote monitoring tools.

Based on rainfall and runoff data and topography data obtained by a drone, the 2D flood simulation was conducted using Nays2Dflood solver in the iRIC software (https://i-ric.org/en/). The result of the simulation showed spatial flood risks[4], which revealed that, once the paddy field alongside the intake weir was inundated by heavy flood, the inundated flow could damage the side wall of intake weir. This suggests that the side wall needs reinforcement by regional resources.

The remote observation tools for monitoring the MHP status should be low cost because low cost allows us multiple observations in several places of the village and even the village people with low monetary income easily getting the tools. A prototype of a remote electric meter was developed by combining a single-board computer, Raspberry Pi (Raspberry Pi Foundation) with a mobile hotspot (Fig. 2). A prototype of a remote camera system was also developed to monitor the intake of the MHP plant. These systems allow us uploading the data to a cloud server and subsequently everyone watching them anytime and anywhere using a smartphone. Especially, the remote camera system can save an operator time and effort to directly visit the MHP plant for checking whether litter and garbage block the intake and stop the water flow into the plant.

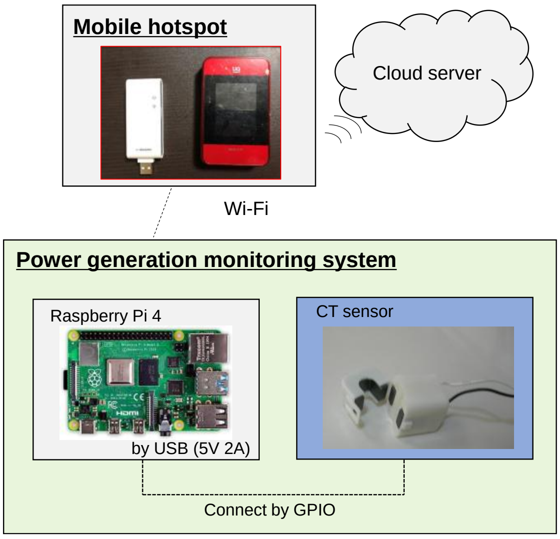

Fig. 2 A conceptual design of the remote electric meter.

Installations and operations of the remote observation tools in Ciptagelar village were challenging due to the pandemic of COVID-19, which made us infeasible to visit the village during these few years. Instead, the prototypes of the remote observation tools were installed in Japan's site, Shiraito Fall MHP plant managed by a private company named River Village Ltd., as a trial. We are now collecting the knowhow for installing and operating them on site. In the future, researchers in Japan will tell researchers in Indonesia how to make and use the remote observation tools. Then, researchers in Indonesia will visit the village to tell the residents it.

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