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Assessing feasibility of operations and maintenance automation – a case of small hydropower plants

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Abstract

The recent developments in Information and Communication Technologies enable remote monitoring and control of distributed work systems and, in turn, development of new products and services related to their operations and maintenance (O&M). The paper focuses on O&M of small hydropower plants (SHP) and assesses the feasibility of different levels of O&M automation. A model for O&M of SHPs is developed and used as a basis for an event-based simulation. A case analysis of 85 Slovenian SHPs is presented. The parameters of the model are determined based on publicly available data and data gathered through a survey amongst the SHP operators. The feasibility calculations are performed for three scenarios describing different levels of automation. The results show how the presented approach can assist in decision-making of individual SHP operators, O&M services providers, and policy makers.

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Keywords: Operation and maintenance; Small hydropower plants; Simulation

1. Introduction

Renewable energy sources, including wind, solar, hydro, tidal, geothermal, and biomass, play a key role in helping the EU meet its energy needs. The EU's Renewable Energy Directive sets a binding target of 20% of final energy consumption from renewable sources by year 2020 [1]. Beyond 2020, renewables will continue to play a key role; a new target of at least 27% of final energy consumption by 2030 has already been agreed upon [1].

Small hydropower plants (SHPs) contribute to around 8% of electricity production within the renewable energy mix [2]. The total SHP electricity generation in EU is currently 44.1 TWh/year, but more than 50 TWh/year can additionally be produced in the future [2].

The average operations and maintenance (O&M) cost for a SHP is between 1% and 5% of the investment costs [3]. These costs are especially high for manually controlled low power SHPs where the operators are involved with SHP's operation 24 hours per day.

The recent developments in Information and Communication Technologies (ICT) enable remote process and condition monitoring [4,5,6] and automated control enabling the transformation of SHP from pure products to industrial product service systems [7,8]. In turn, more efficient operations and maintenance (O&M) can be achieved through newly developed products and services [9,10,11].

This paper studies the feasibility of SHP automation by introducing new products and services into O&M. A case of 85 Slovenian SHPs is analysed. A rule-based model of SHP O&M is developed and simulated for three scenarios corresponding to different levels of O&M automation. It is shown how the presented approach can assist in decision-making of individual operators, O&M service providers, and policy makers.

The highlights of the paper are thus the following: (1) a new rule-based model which at the same time considers both operations and maintenance of SHPs, (2) a real world case study, and (3) an analysis of decision making from different stakeholder perspectives.

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2. O&M of small hydropower plants in Slovenia

This section gives an overview of the case by presenting the data which was used as the basis for SHP O&M model and simulation. The data is acquired from the following sources: (1) the Slovenian Environment Agency (ARSO) data on water flow rates, (2) ARSO data on concessions for water use, and (3) a survey, conducted with 85 SHP operators [4].

2.1. ARSO data on water flow rates

ARSO stores historical data of water levels, flows, and temperatures for most Slovenian rivers in an online, publicly available archive. The data is stored once per day. Consequently one day represents the primary time division in the conducted case-study.

The process of identifying the best measurement station for each SHP consists of first looking up which river the SHP uses based on its geographical location. Then, if there is a measurement station of the same river, the closest one is taken. If no measurement station is found, adjacent rivers are considered. Care is taken that the measurement station of a river with a similar flow profile is taken. For example, if the SHP is on a small river, large rivers are not considered, since their flow profile usually significantly differs.

Overall, 38 measurement stations are identified for the 85 SHPs under consideration.

2.2. ARSO data on concessions for water use

The data on concessions for water use is publicly available for 501 SHPs. Among other data, parameters such as the geographical location of water withdrawal and outlet back to the river, the estimated yearly electricity production and maximum allowable water withdrawal are considered.

The Slovenian SHPs are mainly located in the mountainous regions and in rivers with higher discharge and low net head. Fig. 1 shows the locations of all SHPs. The 85 SHPs under consideration are shown in red.

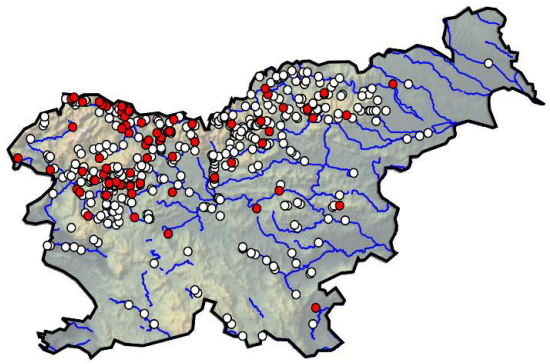

Fig. 1. Slovenian SHPs. The SHPs under consideration are shown in red.

2.3. The survey

To obtain a detailed view of SHP O&M an interview was conducted among 85 SHP operators. The main focus of the survey was related to SHP management, monitoring, control, and maintenance of privately owned SHPs. An example answer is presented in Table 1.

Table 1. An example excerpt from the survey data.

Parameter	Value
River	Poljanska Sora
Time spent per inspection	15 minutes
Number of inspections per day	2-3
Number of sudden stops per year	>30
Number of turbine maintenances per year	15-30
Number of minor maintenances per year	15-30
Time spent for dam maintenance per year	12 hours
Stopped due to high water flow rate	72 hours
Stopped due to low water flow rate	0 days
Control according to available water flow rate	yes

The surveyed SHPs vary greatly in terms of size and O&M procedures. Their electricity production ranges from less than 10 MWh/year up to almost 6 GWh/year. The majority of them produce between 100 and 500 MWh/year.

61% of the SHPs are controlled manually. The rest, which are mostly larger and company operated, are monitored and controlled using a mixture of manual control and control centres. The number of manual inspections of SHPs ranges from once per week to five times a day. The largest part of surveyed SHPs (34%) are inspected once per day. The time of inspection is mostly one hour or less (in 82% of cases), with most operators needing 15 minutes for a single inspection. The average reported total time for inspections is 58 minutes per day and ranges from 0 to 480 minutes.

27% of operators report that their SHPs experience between 0 and 5 sudden stops per year, 37% between 5 and 15, 24% between 15 and 30, and 12% more than 30 sudden stops per year. Turbine maintenance (clogging of the turbine and/or the intake grate, mostly due to autumn leaf fall) is performed between 0 and 5 times per year by most, but for 20% of operators, this represents a real problem, as they report that the turbine maintenance is performed more than 30 times per year. Events that require minor maintenance reportedly take place less than 15 times per year in 73% of cases. On average, 21 hours per year are spent on dam maintenance.

On average, the SHPs are stopped due to high water flow rate for 72 hours per year, but the largest reported value was as high as 612 hours (25.5 days). The stops due to draught, which happen mostly in July and August, last almost 18 days on average, with 125 days reported as the maximum.

62% of SHP operators would be willing to outsource the O&M of the SHP.