EVALUATION OF MICRO HYDRO POWER PLANT (MHPP) USING OVERALL EQUIPMENT EFFECTIVENESS (OEE) METHOD

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ABSTRACT
This paper focuses on evaluation of micro hydropower plant (MHPP) that applies overall equipment effectiveness (OEE) method. MHPP are used on the rural electrification and does not necessarily supply electricity to the PLN grid. They are utilized in isolated and off-grid systems for decentralized electrification. Some identified issues or problems are the results of insufficient site assessment, poor quality of power plant facilities and electro-mechanical equipment, controller equipment and inadequate operation and maintenance. To determine performance of MHPP is done the evaluation using OEE method especially some of the MHPP in districts South Solok. The first step is observing the real condition of MHPP to find technical or nontechnical of primary and secondary data. The data are classified according to which needed by OEE method. It has three main components such as availability, performance and quality. There are seven MHP as the research object. The results are obtained an availability average 68%, performance average 52% and quality average 67%. These achievements shown the MHPP production only reached a value of OEE ie 38%. Therefore, the production in the standard of the Japan Institute of Plant Maintenance (JIPM) is a bad class. The strong issues or problems of MHPP that found are management 17.2%, control systems 7.3%, turbine 10.6%, generator 32.7% and transmission 31.9%. Management includes customer payment, skill of the operator and maintenance. Generators are major contributors to the problem because there are many MHPP does not have automatic control equipment.

Keywords: evaluation, MHP, OEE, JIPM.

INTRODUCTION
Micro Hydro Power Plant (MHPP) is that utilizes the river flow (run off river). MHPP is typically used on the rural electrification and does not necessarily supply electricity to the PLN grid. They are utilized in isolated and off-grid systems for decentralized electrification. Some identified issues or problems are the results of insufficient site assessment, poor quality of power plant facilities and electro-mechanical equipment, control equipment and inadequate operation and maintenance [1]. Today, MHPP has been developed into a grid system to serve a region. The controller equipment is required to ensure the parallel operation of power plants in power system. Such controller is also required for Micro hydro power plants to work in interconnected micro hydro power plants. The approach with frequency droop to make a Mini-Grid model has been studied that describes performance of simulated droop based electronic load controller for interconnected micro hydro power plants or mini-grid [2]. Therefore, it is required quality of power generation in accordance with the standard. Similarly, the equipment that used must also be standard but it is limited. West Sumatra Province has abundant water potential to be used as a electric power generation renewable energy in the large, medium and small capacity. Utilization of water as small scale power plants, that called micro hydro power plant (MHPP) is widely used in remote areas. More than 150 power plant station in West Sumatra Province with capacity are various 10 kW, 16 kW, 20 kW, 22 kW, 24 kW, 26 kW, 40 kW, 50 kW, 64 kW etc. Based on 2 investigation, several problems are found in MHPP such as; short life time, short duration operation, bad voltage and frequency quality [3],[4],[5]

The main objective of this study is to evaluate of MHPP quality that applies the overall equipment effectiveness (OEE). To determine the condition of MHPP is used the standard of the Japan Institute of Plant Maintenance (JIPM) [6]. It is required to determine the main issues of MHPP, so it can be obtained the step to be grid system or mini grid system. In this research is taken eighteen of MHPP as sample that location in South Solok district. Recently, several researcher have found the voltage and frequency control equipment of MHPP such as micro hydro power generation based on fuzzy logic control such as micro hydro power generation based on fuzzy logic approach in order to improve voltage profile of alternative power generation [7].

MATERIAL AND METHODS

a) Overall equipment effectiveness (OEE)
OEE is the simple method to evaluate that practical and powerful to evaluate the production system. This method usually takes the most common sources of manufacturing productivity losses and places them into three categories such as; Availability (A), Performance (P) and Quality (Q). Generally, that are represented in percent (%). OEE is defined as the ratio of fully productive time to plan production time [8],[9]. The schema of OEE System is shown in Figure-1. Determine of Overall Equipment Effectiveness (OEE) is used “the six big losses”, such as; Down time loss that influence of availability. Speed loss that influence of performance. Quality loss that influence of quality.

In practice OEE is calculated as;
OEE = Availability x Performance x Quality  

1) Availability (A): Availability is defined as the ratio of operating time (which is simply planned time - productionless down time) to planned production time, and accounts for loss down time. It is calculated as:

\[ A = \frac{\text{Operating Time}}{\text{Planned Production Time}} \times 100\% \]  

Operating time is the length of MHPP operational a year, and planned production time is length of operating expectations a year ie 8760 hours.

2) Performance (P): Performance is defined as the ratio of net operating time to operating time, and accounts for speed loss. In practice it is calculated as:

\[ P = \frac{\text{Ideal Cycle Time} \times \text{Total Pieces}}{\text{Operating Time}} \times 100\% \]  

Ideal cycle time is defined as the ideal time that is used to result a product. Total pieces are number of product. Operating time is the real time of length operating a year ie 8760 hours.

3) Quality (Q): Quality is defined as the ratio of fully productive time (time for good pieces) to net operating time (time for total pieces). In practice it is calculated as:

\[ Q = \frac{\text{Good Pieces}}{\text{Total Pieces}} \times 100\% \]  

Japan Institute of Plant Maintenance (JIPM) had been had standard benchmark of OEE that implemented in the world. OEE base on the standar benchmark JIMP that shown in Table 1.

Table-1. OEE standard benchmark of JIMP.

<table>
<thead>
<tr>
<th>OEE (Overall Equipment Effectiveness)</th>
<th>JIMP</th>
<th>Percentage Value</th>
<th>OEE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect</td>
<td></td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>World Class</td>
<td></td>
<td>≥ 85%</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td>≥ 60% and &lt; 85%</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>≥40% and &lt; 60%</td>
<td></td>
</tr>
</tbody>
</table>

Usually, OEE world class according to standard that recognized is; Availability ≥90%, Performance ≥ 95%, Quality 99.9% and OEE ≥ 85%.

b) Flowchart

The step-by-step process on how to evaluate the MHPP is illustrated in Figure-2.

Figure-2. Flowchart evaluation of MHPP using OEE method.

The first step is survey to take the data to MHPP area especially South Solok Distinct. The data include MHPP equipment, operation, management, maintenance, capacity, costumer, distribution and load. The data are grouped and calculated in accordance with purpose of the OEE method. Further, determining value of availability (A), Performance (P), Quality (Q) and the overall equipment effectiveness (OEE). These results are analyzed to assess the condition of MHPP, and then used to determine the corrective measures. The cause of disruption MHPP are recorded and calculated the percentage value...
of interference. It is required to determine the cause of the biggest distrubents of MHPP.

c) Data and calculation

The data are collected by survey to each MHPP location, that include rating capacity, actual generated energy, customer amount, actual time operation, total available time, total set up time and total break down time in a year. There are eighteen MHPP as sample data, such as (1) MHPP Ulu Suliti II, (2) MHPP Ulu Suliti IV, (3) MHPP Koto Baru, (4) MHPP Pulakek, (5) MHPP Karang Putih, (6) MHPP Sungai Bangku and (7) MHPP Simacuang. (8) MHPP Manggih, (9) MHPP Wonojo, (10) MHPP Berta, (11) MHPP Liki Tengah, (12) MHPP Sungai Aia Ateh, (13) MHPP Batang Lolo, (14) MHPP Paninjauan, (15) MHPP Taratak Tinggi, (16) MHPP Pasie Panjang, (17) MHPP Sapan Salak, (18) MHPP Sapan Sungai Nan Duo. Operating data of MHPP that have been found in location can be shown in Table 2.

Base on data in Table-2, availability (A) of MHPP Ulu Suliti II can be calculated using equation (2), where operating time can be obtained of total availability time minus time breakdown minus time set up, so;

\[
A = \frac{\text{Total Time} - (\text{Time Breakdown} + \text{Time Setup})}{\text{Total Time}} \times 100\% 
\]

\[
A = \frac{8592h - (4439h + 189h)}{8592h} \times 100\% = 48\%
\]

Table-2. Operation data of MHPP in a year.

Several issues or problems that cause MHPP fail operate as shown in Table-3. Performance of MHPP Ulu Suliti II can be determined using equation. (3), where ideal cycle time can be obtained by multiplied customer amount with generated energy multiplied actual time, then;

\[
P = \text{Costumer x Generated Energy x Actual Time} \times \frac{100\%}{\text{Costumer x Energy Capacity x Total Time}}
\]

\[
P = \frac{25 \text{ Kk} \times 41344 \text{ kWh} \times 4134h}{825 \text{ Kk} \times 87600 \text{ kWh} \times 8595h} = 23\%
\]

The Quality of MHPP Ulu Suliti II can be determined using equation. (4), where good peace can be obtained with to devide total generated energy with total energy capacity, then;

\[
Q = \frac{\text{Total Generated Energy}}{\text{Total Energy Capacity}} \times 100\% = 47\%
\]

Further, OEE can be determined by using equation. (1), then;

\[
\text{OEE} = 52.5\%
\]

The parameter A, P, Q and OEE for the others MHPP can be calculated same as way the above, further the result as shown in Table 4.

Table-3. The causes and frequency of operation failure MHPP.
RESULT AND ANALYSIS
The MHPP that had been studied are obtained the average OEE is 57% and it is low category based on JIPM standard. Where there are 38.8% that bad category, 27.7% the normal category and 33.3% only the world class category, as shown in Table V. The result shows that OEE of MHPP Manggih only having near in to perfect class category ie 92%. The reason is MHPP Manggih which is a new MHPP that has complete equipment, operating continuously and breakdown time briefly.

MHPP Pulakek and MHPP Sungai Bangku have OEE value is 78% that are the normal category. These MHPP operate continuously, have complete equipment, however the total breakdown time is longer than MHPP Simanunggal.

While, the other MHPP having a low category because OEE value is lower than 40%. Caused of MHPP have been operated for long time, equipment incompletely, operating time 8 hours every days and also lack management. To increase the OEE value of MHPP can be done with to search main issues of MHPP. MHPP issues can be grouped in to 5 parts, such as; management, control system, turbine, generator and transmission line. Table-6 and Figure-3 are shown the issues of MHPP that studied.

The main damage that often happen in the MHPP is at the generator part ie 32.7%, especially the carbon brush and generator winding. That are caused of over load or over frequency of generator, while the generator generally don’t have an automatic controller equipment. If they have an automatic control equipment which usually use an electronic load controller (ELC). The principle of ELC is when the consumer load is decreasing then ELC will throw to dummy load [1]. The impact is that the generator and turbine always operate at full load condition. It can break the generator winding or the bearing of turbine. The transmission line give a contribution to disturb an operation of the MHPP ie 20%. It is caused of a bad construction or struck a fallen tree.
The management of MHPP is the seriously issue because it has strong impact with electricity bills and operator salary. Lack awareness customer to pay an electricity bills that cause manager of MHPP difficult to pay maintenance cost and operation cost.

CONCLUSIONS

Evaluation of 7 MHPP in South Solok districts has been discussed. Method of evaluation that used is OEE. The result are obtained that the average OEE value is 57%. It is low category. The strong issues or problems of MHPP are management and equipment. Management include customer payment, operator skill and maintenance while equipment issue is the automatic control equipment.

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