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The Implementation of Isolated Microhydro Grid on the Community Cuisine Learning in Rural Area in North Sumatera

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***Abstract*—Hutajulu is a village of 450 households with a minigrid supplied solely by a 45kW microhydro system. The very weak grid performance during the dry season is presented and the interactions between energy use and grid operating practices are investigated. The results are given for eight households, trialing four types of electric cookers, in order to reduce firewood use. There is considerable interaction between the electric cookers and the power system. The effects of the power system and the electric stoves on the cooking preferences is also revealed.**

Keywords—Weak grid, Microhydro system, Electric stoves, Minigrid.

I. INTRODUCTION

North Sumatera has 2500, off grid, microhydro plants with a total installed capacity of 22MW [1]. There are many various issues exists in microhydro plant operation and the average plant load factor is claimed to be 20% [1]. The deforestation and health related issues from the traditional practice of cooking over wood fires, has created the concept to investigate cooking electrically, powered by the microhydro plants. However, in reality, some microhydro systems fully loaded.

A study conducted in 1994 with low wattage electric cookers in the remote community of Dolokjulu, powered by a microhydro system, demonstrated the viability of electric cookpot under some favourable circumstances [2]. The free fuelwood and limited generation capacity created challenges for the scalability for the low wattage electric cookpot.

In North Sumatera, energy consumption of traditional fuelwood, constitutes 79.7% of total energy consumption [3]. The residential sector consumes 94% of the fuelwood for which cooking accounts for 57% of the energy usage followed by heating, water boiling and other purposes [3]. Diseases caused by indoor air pollution are claimed to account for about 1500 annual deaths in Indonesia [4]. The use of wood is known to be a major factor in deforesting Indonesia and often consumes many hours a day in collection [5].

The factor given above are an incentive to investigate the viability of electric cooking appliances. However, the electric grid is usually very weak, in the remote areas, which are often powered by microhydro driven mini grids.

The remote village of Hutajulu has a 29kW microgrid, powered by a micro hydro system. The performance of nine electric cookers in eight households in Hutajulu, are investigated. Similar methodology was used as in the previous study trialling induction hobs performed in the same village in the summer of 2018 and is presented in [6].

This paper primarily focuses on the results of the data analysed from the microhydro system that will enhanced the concepts

Fig. 1. Use of traditional wood stove in the Hutajulu village.

Fig. 2. Map of North Sumatera showing the location of the work at Hutajulu village mapped from geographical information software tool.

II. HUTAJULU MICROHYDRO SYSTEM - ITS DEMAND AND OPERATING CONDITIONS

A. *Hutajulu microhydro plant*

The microhydro system at Hutajulu village is a 29 kW micro-grid system electrifying 450 households, IEEEcommissioned in 2017. The community microhydro committee leases the microhydro system to a private business, as the microhydro committee was unable to run the system.

A mid-mountain highway passes right away through the community which has led to the development of a small commercial market place. The electric load is most significant during the evening peak time in the phase where the commercial market is connected.

The Hutajulu microhydro system has been running at full capacity since early 2019. The load has increased to the degree where the electricity is inadequate during the dry season (March to mid June).

The system provides power to 12 industries whose power requirement ranges from 1kW to 10kW. The industries requiring higher power are the timber mill, a metal workshop and a bakery. The recent addition of a 10kW, three-phase electric grinding mill is allowed to run only during the night time. Most industries are scheduled to operate only during the day time, although may not be practised. Most households in the commercial market area are reported to use freezers.

The lack of sufficient water in the dry season prohibits expansion of the microhydro system. Observations suggest the urgent need for demand side management, while the community eagerly awaits the national grid to arrive.

B. *Microhydro system operation*

The 29kW rated microhydro system consists of the synchronous generator connected to a crossflow turbine with the flow rate of 65 litres per second at 72m head. The electronic load control system is based on voltage control which individually controls the phase current through a ballast load. The electronic load controller regulates the voltage of the generator by switching the ballast heater, depending upon the demand. The frequency is not directly controlled, but allowed to vary.

The electrical measurements from the microhydro system were collected during the dry period between May 1st to May 21st.

Five watermills are present between the diversion to the microhydro system and the microhydro turbine. Water from the canal is diverted to reach the three water mills. Although the operation of the grinding mills is scheduled, the microhydro system operator often faces issues with mills operating at unscheduled times. Strict regulation is difficult as the community depends on the water mills, which produce wheat flour largely for flat breads.

The water flow is manually reduced by a butterfly valve, such that the generator is operated slightly above the demand load, the surplus power being absorbed by the ballast loads. Hence, the operator stays alert in most hours of the day, manually controlling the water flow through the butterfly valve. Most microhydro systems in North Sumatera operate similarly. Fig. 3 shows an inside view of the power house when the operator is controlling the water flow before the turbine.

The reasons for operating the microhydro at a reduced power level whenever possible, is that operating the microhydro plant to full capacity is associated with early wear and tear. The common component failures are electrical in nature which are mostly electronic load controllers, ballast heaters or the generators [7].

Fig. 3. Operating controlling the water flow to the turbine through the butterfly valve (Source: Surendra Pandit).

Fixed outages occur two times a day, 6am-9am and 4pm-5pm, sometimes to operate the water grinding mill. During the wet season, the outages are from 9am-10am and 4pm to 5pm mainly to "rest" the system with the intention of reducing maintenance issues, as is common throughout microhydro's in North Sumatera.

Like the Hutajulu microhydro plant, most microhydro plants are located in very remote locations, with a consequent high repair cost and long time to repair - which could be six months.

It was observed that the operator sheds the load in some areas as required. The load shedding also had to be reorganized after the electric cookers started operating.

Fig. 4. Water powered stone grinding mill positioned in the canal way to the microhydro plant (Source: Surendra Pandit).

III. Microhydro System Performance

The microhydro data was collected from 1st May to 21st May. Many outages are observed during the set cooking hours of 5pm to 7.30pm. Significant fluctuations in voltage and frequency were observed. The plot indicates several power outages every day. The power outages are either regular fixed outages, outages for repair and maintenance, or due to overloading.

Power outages were also observed for eight days during the day time after the electric cookers were installed. The outage was to repair the distribution lines which can also be observed. The wooden poles used as electricity distribution lines have been reported to cause frequent problems. The power outages due to overload were mainly during the evening hours and sometimes in the morning hours due to the added electric cooking load.

It is observed that voltage and frequency are relatively more stable during the morning hours before 5am. The morning peak time starts from approximately 5am when the load gradually starts to increase. The frequency of power outages after the installation of electric cookers increased in evening hours. It demonstrates the power outages due to overload. The system is then shut down to disconnect some phases manually, before the system is turned on again.

It illustrates a wide range of voltage variation at different operating frequencies during the measurement period. It shows the occurrence of varying voltage and frequency in 4.5Hz and 8V bins. Voltage and frequency between 210V-230V and 49Hz-52Hz respectively occurs largely.

The system sometimes operates at low voltage and frequencies near 150V and 40Hz . The generator makes a different noise in this operating condition which acts as an alarm to the operator. The operator then either increases the water flow, if possible, or shuts down the system.

The highest fluctuations in the voltage and frequency can generally be observed during the night time, specifically between 6:00pm to 9:00pm . The short power outages were most frequent at these hours of the day.

The power outages can be correlated with the use of electric cookers and the pre-existing night time load at Hutajulu. The commercial part of the village is connected to the blue phase. The blue phase was measured to have approximately 10kW during evening hours. The blue phase is also the phase with the highest load relatively.

IV. Types of Electric Stoves Tested

Eight participants agreed to participate in the cooking practices survey who were provided with one of four types of electric cooker.

The type and quantity of food cooked, time of cooking, wood, liquid petroleum gas, and electricity, used and energy

consumption were collected during the test period to investigate use of the electric stoves.

Four induction hobs, two infrared hobs, two storage hobs and one electric pressure cooker were provided. Due to the limited electrical power available, all the cookers were restricted to approximately 1kW of power, either by disabling higher power functions or by voluntary restrictions on the user.

The study utilized the induction cooker called IMEX ICP1 model which would not power up at turn on until the desired power level is chosen. All the pushbuttons in the keypad indicating power levels above 1kW were blocked to prevent additional stress for the micro microhydro grid.

The infrared cookers have a power factor was measured 0.3 at 200W for the infrared cookers.

Energy storage cookers work by storing heat in the iron plate surrounded by the heavy top and bottom insulating material. The nominal power is 400W, which takes the metal to 600deg within 6 hours. Although the energy storage cookers proved to be very convenient to use in a constrained microhydro grid, the present structural design and its weight create issues to transport and repair. The energy storage cooker design had limitations such as the inside insulation sometimes becoming detached after a week of use.

The electric pressure cookers are much efficient compared to other cookers with their power capacity ranging from 900W to 1.2kW [8]. Multiple cooking operations like boiling, steaming and frying are possible.

V. Cooking Food

It is essential to understand what people eat and how it is cooked to find energy efficient cooking alternative to fuelwood. This section briefly discusses the results of the data collected from the households who used electric cookers during the test period.

Rice, flatbreads, lentil soup and vegetable curry comprise the staple foods in North Sumatera. Usually, a hemispherical iron or brass pot is used for cooking rice along with vegetables. Flatbreads are prepared in a particular type of flat iron utensil called Tawa which has a minimum thickness of 4 mm to ensure that the flatbread does not burn.

Generally, a typical meal consists of a rice based meal or a flatbread based meal with vegetables, usually cooked as curry or with meat (less frequently). Mostly, there are only two meals per day. One meal is prepared in the morning 7.30-.830am, while the evening meal and preparation time could vary between individual households.

Overall, 486 and 435 dishes were recorded in the pre electric cooking and electric cooking phases respectively.

The food that is generally consumed by users and the frequency of common meals is shown. The major distinction between the baseline and the test phase is the quantity of flatbread-vegetable meal which has decreased by 51% while the rice vegetable meal increased by 53% during the electric cooking phase. The quantity of rice, lentil soup, meat and spinach was similar in each phase.

The participants found rice and lentil soup relatively easy to cook with the electric cookers. The flatbread was more challenging to cook due to the lower temperatures available with the electric cooking, and so reverted to their wood stoves for flatbread. The taste was also a factor, with some people preferring the smoky flavour generated by wood cooking.

VI. Effect of the Weak Grid on Electric Cooking

Due to the erratic and frequent, short interruptions of electricity during the cooking hours, some users used wood stoves and liquid petroleum gas during the electric cooking data collection period.

Electric stove users found that the dishes were very difficult to cook in the electric cookers with either food being wasted or shifting to alternative means of cooking. Some users reported that the vegetables also did not cook well because of the power supply problem.

Three participants reported that the 10kW electric grinding load was being operated earlier than its scheduled hours, and therefore was responsible for the electricity outages.

It shows the operating condition of microhydro plant with voltage and frequency when the three phase 10kW electric grinding mill starts. It shows the three phase voltage, current and a frequency plots during the period when the electric grinding load operated. The grid voltage stays at 150V even after the system is turned back on. The electric grinding load, in addition to the night time baseload at reduced flow condition, suggests that the microhydro system is unable to handle such loading conditions at the night time during the dry period.

The microhydro electrical parameters of the red phase are shown between 17:00 to 21:00 on May 11S after the participants started using the electric stoves. Point I represents the end of the daily scheduled outage. As soon the system is turned on, the microhydro plant bears immediate load as many of the appliances are not turned off. The cooking occurs between 17:00 to 20:00. The load rises to 25A several times before point II while the voltage and frequency stays at 150V and 50Hz range.

System is shut down as shown for a brief period of time as the system can't handle the increase of load current. Before the system is shut down, the voltage is seen to drop close to 50V, 190V and 150V. 25A steady state current per phase may not be a critical load for a 29kW system. However, the microhydro plant struggling to operate stably can be understood which shows the plot of total generation and load power calculated by adding instantaneous power of each of the phases. The microhydro system was operating approximately at 50% of its rated capacity on average during the cooking period. This indicates the low water flow the water leakages in the canal. It also shows that the total generation power drops immediately with the increase in load current dropping the voltage and frequency to a critical value just before the system is shut down.

Due to the highly constrained generation, the operator shuts down the system and turns it back again after disconnecting some load from the grid. The point II is where the operator sheds the load connected to one of the phases and the load current grows gradually until point C. The load shedding is implemented to provide electricity to the households where the electric cookers were distributed.

Similar instability in voltage and frequency is observed during most days as also indicated in section III during the cooking stove test period.

The light industries have a fixed schedule to operate during the day time from 10:00am to 4:00pm. The electricity during the day time during the test period experienced long outages for maintenance. This led to some industrial load which used electric welding to shift during the morning hours.

It illustrates the voltage and frequency condition of the electricity system on the red phase when the electric welding load was used. The connection and the disconnection of the welding stick with the metal piece causes a sudden rise and fall in load currents. As a consequence, the voltage swings between 230V to 200V. It is assumed that certain industrial loads were frustrated trying to operate during the morning and the evening hours, which coincided with the cooking hours. The addition of industrial load may have caused extra stress to the electricity system along with the electric cooking loads during the test period.

The operation of some industrial load outside of scheduled time suggests the need for a new concept of regulation such as a high tariff or a smart load cut off system. This may discourage the industrial customers and therefore a smart distribution side management system may be of dire need for a short term solution.

Long hour outages during the day time caused issues with the energy storage users. However, the users were able to cook food effectively compared to other cookers that require instantaneous power. It shows an example of the voltage condition of the microhydro system before the electric cookers started operating during a mid day time. The day time load current is significant which causes heavy voltage fluctuation between 230V to 150V. In general, the load in the blue phase again seems to be higher relative to other two phases, however the fluctuation seems to be higher in the red and yellow phases. The generation power varies between 15kW to 25kW as shown in the bottom plot. The range of generating power suggests that the flow in the canal is higher on May 4th compared to the evening hours in the following days. Again, longer outages and erratic voltage issues may be challenging for storage type cookers.

VII. Effect of the Electricity Supply System on Electric Cooking

The power outages during the day time were significant. The power outages during the day time are due to distribution pole maintenance. It is reported that the heavy rainfall during the monsoon causes the landslide with the wooden poles falling. Wood decay and breakage is another cause making the wooden pole highly unreliable in Hutajulu area.

Cooking appliances like energy storage cooker requires electricity during the day time so that it can store enough heat. Long hour outages during the day time caused issues with the energy storage users. Despite this, the electric storage cooker users were able to cook food effectively compared to other cookers that requires instantaneous power.

Very weak MHP grid has both a short run and a long run effect on electric cooking. Cooking takes longer time with low voltage. Additionally, frequent outages make the food uncooked in short run as the food are shifted to other stoves. In the long-run, weak and unreliable grid affect the user's perception by reducing the benefits from electric cooking technologies.

Eight households reported using electric stoves as a primary cooking device. User's used the electric stoves to prepare at least one dish 90% of the time during the testing period. Remaining 10% accounted for inability to cook due to power outages and low voltage issues. Among the four different electric stoves, users found the induction hobs to be more suitable for cooking major dishes. The reason was recorded to be because of user- friendliness, adaptability and safety features. Although, its high power demand posed a significant issue during the cooking hours. At the same time, the storage cooker is more suitable for cooking in a pressurized vessel where cooking at least three dishes may be possible at high temperature start. Cooking in open vessel utensil leads to extreme heat loss limiting the cooker to cook only one dish. The users found cooking with storage cooker to be convenient as no instantaneous power is required during the cooker time. However, one user faced difficulty with its design as the inner insulation started to fall off gradually. The electric pressure cooker is not suitable to cook flatbread due to its design structure but more effective, consuming less energy to cook rice, vegetable and lentil soup. From the user experience, it is noted that electric pressure cooker may be more efficient with the greater quantity of rice for big family members, whereas induction hob is relatively suitable for small family size provided the availability of reliable power supply.

VIII. Conclusion and Discussion

The microhydro electricity supply at Hutajulu is highly constrained. The constrained generation mixed with power outages in the microhydro system poses significant issues for the uptake of electric cooking possibilities at least with the electric cookers tested in the scope of this study. However, the viability of using about ten electric cookers during the wet season may be possible but is not a long term solution, given that there are 450 households in this village. The need for innovative low power device cooking appliances with smart distribution side management would be a better path for the Hutajulu microhydro utility.

The data collected from the microhydro system shows that the generated power is barely enough to supply the demand, which is increasing each year, during the dry season. The evidence of short power outages and load curtailment gives a clear indication that the wide adoption of electric cooking with the stoves tested is not possible currently.

The voltage fluctuations and unplanned blackouts significantly affected the cooking duration and the users shifted to using alternative fuels such as fuelwood and liquefied petroleum gas for cooking.

Part of the solution may be the use of highly efficient electric cookers, which are controlled to use any excess generating power available. This was tested as an off peak cooking load and was able to cook 7.5l of food overnight with only a maximum of 140W of power [9] [10].

There might be some possibility of usage of electric cookers during the wet season, but its scalability cannot be expected unless the power generation is reinforced substantially or at least the demand side is managed effectively.

Energy storage cookers were reported to be more adaptable compared to other cookers as it did not require instantaneous power during the cooking time. However, the cooker's design poses issues in terms of exposed hot cooking surface, overall design and awkward weight.

IX. Acknowledgement

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