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Sizing a Photovoltaic Solar Water Pumping System (PVWPS) for supplying water in Nzulo's locality, Masisi Territory

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Abstract:- Nzulo is a locality located in the Kamuronza Groupement, Masisi territory, approximately 6 km from Sake in the Democratic Republic of Congo (DRC). Despite the enormous water potential available in the country, the population suffers from a lack of access to drinking water. For some time now, he has observed massive population movements due to the security situation in the east of the Democratic Republic of Congo, which continues to deteriorate, particularly in the province of North Kivu. From October 20, 2022, there is a resumption of clashes in the territory of Rutshuru, which extend to the territory of MASISI. According to the alert shared by the leader of the Kamuronza group and confirmed by a humanitarian source, approximately 200,000 people, distributed in 4000 households, have been displaced and currently reside in Nzulo. However, as there is no water pumping system in this locality, displaced people have urgent WASH (water, sanitation, and hygiene) needs. Referring to the estimate of daily water consumption per person, made by the United Nations, which is 20 liters, the water needs of the population of Nzulo is 200 000 liters/day or 400 m^3/day. Considering the extension factor, we consider a supply of 500 m^3 of water. This paper concerns the sizing of the drinking water supply system in the locality of Nzulo. Water intake will be from Lake Kivu, by gravity flow. The pumping system will be done with a 28.8 kWc photovoltaic system because in the locality of Nzulo the electricity network is absent.

Keywords:- *Solar Energy, DC-AC Converter, Water Pumping System.*

I. INTRODUCTION

Nowadays, for irrigation needs, domestic use, drinking, livestock needs and industrial needs water is required. That's why, water pumping has become an indispensable task to live. In areas where the electricity network is absent, efforts are being made to use solar power for water pumping. A photovoltaic pumping system uses PV technologies to convert sunlight into electricity to power a pump set to transport water from its natural source to the point of use. PV panels are connected to a motor (DC or AC) that converts the supplied electrical energy into mechanical energy which is converted into hydraulic energy by the pump.[1]

II. WATER SUPPLY AND SANITATION IN THE DRC

The Democratic Republic of the Congo (DRC), the continent's most "water-rich" nation, has an urgent drinking water supply crisis and is believed to hold 52% of the continent's surface water reserves (rivers, lakes, and marshes). Up until recently, the trend in water supply coverage was in regression due to the deteriorating status of its water infrastructure, which was weakened by years of underinvestment, violence, and a rapidly rising population. There have been significant social and public health repercussions from water service outages.[2]

The Democratic Republic of the Congo's (DRC) vast freshwater resources notwithstanding, the primary concern facing the country's water sector is addressing the poor availability of clean drinking water for its quickly expanding population. The water infrastructure and services of the nation are seriously deteriorating as a result of years of war-related facility devastation. Both in rural areas and increasingly in quickly urbanizing cities, the weakest segments of society have been disproportionately affected by the loss in service delivery and rising water bills. [2]

Only 3% of households in the Democratic Republic of the Congo have a handwashing station with soap, 52% of people have access to better water facilities, and less than 29% have access to improved sanitation. Therefore, the adoption of better sanitation facilities is even less common than improved water access. These access rates are far lower than the Sub-Saharan averages, and as Figure 1 shows, even when measured against its nine immediate neighbours, the Democratic Republic of the Congo has the second-lowest rate

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of improved water access and the fourth-lowest rate of sanitation access. [3]

III. REGIDESO

In its current legal form, the "Régie de Distribution d'Eau" (Regideso) is a public business that was established in 1979. It is exclusively in charge of the DRC's population's access to water. It has serious issues with liquidity. Wages in certain areas have not been paid for years, and the SNEL power organization frequently stops the delivery of energy when bills are not paid. Thirty-two of the distributor's ninety-four plants are inactive. Only a portion of the 62 operational power plants' capacity is utilized. Because there is not enough money to invest in the hydraulic network, the lines are in extremely poor condition. [4]

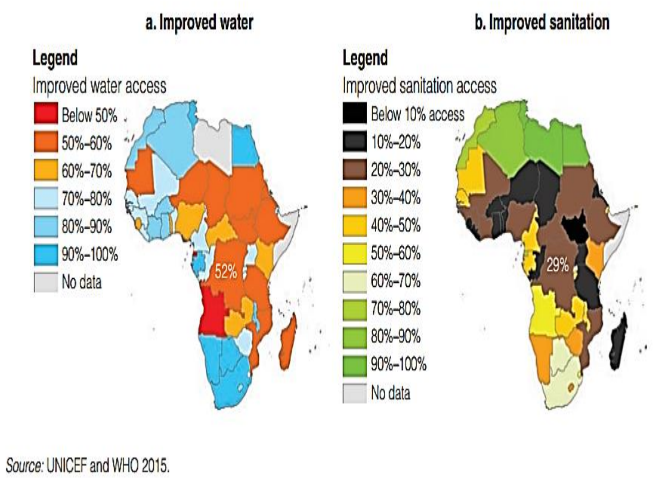

Fig.1: Map of Access to Improved Water and Sanitation in 2015 of the Democratic Republic of Congo in the African Context[2]

IV. LOCALITY OF NZULO AND THE CITY OF GOMA

Nzulo is a place in the Democratic Republic of the Congo's Sud-Kivu province. It is situated within the Virunga National Park's Masisi area.[5] The Nzulo displacement site is ten minutes on foot from the main Goma-Sake road and roughly fifty to sixty minutes by car northwest of the city of Goma.

Sake, a small trading town with the largest market close to Nzulo's displacement site, is approximately a minute's drive from Nzulo.

One of REGIDESO's remaining centres, the city of Goma in the Democratic Republic of the Congo, is powered by two gravity-serving reservoirs and numerous pumping stations with a combined capacity of about 2,000 kW. The DRC's National Electricity Company provides the pumping stations with electricity.

(SNEL) which operates the hydroelectric dam of the Ruzizi I located about 110 km south of the city.

Goma's low electricity supply causes the REGIDESO pumping stations to experience extended power outages, which interrupts the city's drinking water supply and occasionally leaves the North, West, and East sections of the city without any water at all. Due to this shortage, most people are compelled to obtain raw water from Lake Kivu, which raises the price of potable water. It also increases the risk of traffic accidents caused by people travelling to the lake, the exploitation of children who must carry excessive weight over long distances, and the spread of water-borne illnesses.[6]

V. CONTRIBUTION OF THIS PROJECT

According to the United Nations (UN), an individual requires 20 litres of water per day to meet their basic needs. Poor people shouldn't have to pay for that basic amount of water because they can't afford the water bill.[4]

Based on UN estimates of water consumption, Nzulo's population of about 20,000 people needs at least 400000 litres (400 m^3) of water per day to meet their needs.

To provide more people in the city of Nzulo with access to drinkable water, we are sizing a photovoltaic water pumping system in this paper.

VI. CONSTITUTION OF A PHOTOVOLTAIC WATER PUMPING SYSTEM (PVWPS)

A solar pumping system usually consists of (See Figure. 2):

- The photovoltaic generator,
- The electric pump group,
- Control electronics,
- The storage part,

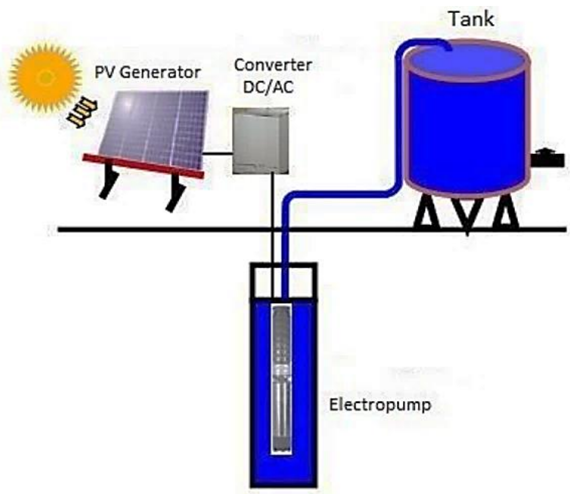

Fig.2: Simplified synoptic diagram of a PV Pumping system[7]

VII. SIZING DIFFERENT COMPONENTS OF A PVWPS

A. Water requirement

Nzulo requires 400 m3 of water per day to meet their needs. Considering the extension factor, we envision 500 m3 of water being supplied to the populace through the building of a gravity water tank atop a mountain in Nzulo. amount of water required by Nzulo.

B. Water source

There are two types of water sources: surface (pond, stream, or spring) and subsurface (well). The primary water source in Goma is Lake Kivu, which serves as a significant urban boundary. Because a surface water source is being used, the pump intake must be properly screened to prevent silt and debris from the surface water body from being pumped into the system. If caution is exercised from the pump intake to the delivery point or point of use, the water pumping system will function as intended.

Since Lake Kivu is known to contain some small fish species, the Ministry of Environment must also provide certain requirements for the pump intake to protect the environment. Before the pumped water reaches the storage tank, it will be examined and treated because it will be utilized for a variety of purposes, including domestic use, irrigation, and the feeding of both humans and animals. To do that, Lake Kivu water is chlorinated using a few tiny pumps.

C. Water storage

Instead of storing electrical energy, the primary goal of the battery-free PVWPS is water storage. Utilizing battery storage has the drawback of requiring an advanced control system. It might therefore greatly raise PVWPS's expenses and maintenance needs. Thus, there needs to be a demotivation to use battery storage. This is a result of PVWPS's recent cost increases. Furthermore, complexity usually outweighs the obtained advantages.[8]

Water storage is an essential part of solar-powered water pump systems because it can be used to store enough water during peak energy production to meet water needs in the event of a lack of solar sunlight or problems with the power system. According to the UN Development Department, each person only needs 20 litres of water per day, so our 500 m^3 tank can supply water to roughly 25000 people every day. Solar insolation and PV Panel location.

The site under study is located near Sake City/DRC. Its geographical coordinates are Latitude 2 ° South, 1 ° 40 ' North and longitude 27 ° 47' West, 30 ° 07 'East.

This location has a solar irradiance level which is suitable for solar installation. It receives an average irradiance of about 4.64 kWh/m^2/day (average of all the year). The amount of solar insolation (peak sun hours) available at the site where PV panels are located (city of Nzulo) is 7 hours. The solar array should be placed near the pump to minimize the electric wire length and thus any energy loss. That can reduce also the installation cost.

D. Flow rate for the pump

The daily water needs of the operation (500 m^3 in our case) are divided by the number of peak sun hours per day to determine the flow rate for the pump..[8]

E. Total Dynamic Head (TDH) for the pump

The total of the vertical lift, pressure head, and friction loss determines a pump's TDH. Only the piping and accessories between the point of intake (inlet) and the point of storage (i.e., the storage tank or pressure tank) are subject to friction losses. Usually, gravity feed is used to move water from the storage tank to the point of use, which is the trough. As a result, when sizing the pump, friction losses between the storage tank and the point of use are not affected by the pump.[8]

The resistance to water flow caused by the pipe's interior surface is known as friction losses. They are defined by the pumping rate and the pipe's size (diameter and length), and they are expressed in terms of equivalent height. Now let us compute the Total Dynamic Head. The vertical lift is equal to the product of the static height and the static lift of water. Thus, in our instance, the vertical lift is 110 m since the static lift is 10 m and the static height is 100 m. The friction loss is computed using the pipe's diameter of 150 mm (5.9 inches) and length of 188.75 m (let's use 200 m), and the flow rate of cause the shart of friction loss for "**Hunter industries**" which is our pipe model; is represented in gallons per minute as we know that 1 US gallon is equal to 3.785 llitres A friction loss table (see friction loss characteristics schedule 40 standard steel pipe c=100) uses the pumping rate and the inside diameter of the pipe to give a friction loss in terms of vertical feet for every hundred feet of pipe. According to the table FL equal to 0.63 $^{PSI}/_{100\ feet}$ because the flow is taken at and the diameter at 6 $inches$ all the length.[9]

$$Lenght = 200\ m = \frac{200}{0.3048}\ feet = 656.16 \text{ feet}$$

So

F. Pump selection and associated Power requirement

We can calculate the required pump size and the amount of power from the PV array once we have established the required water volume, the properties of the water source, and an approximate idea of the vertical and horizontal distances that the water will be pumped. To make sure the pump can deliver the needed flow against the known TDH, the pump should be chosen using pump performance curves. According to our design, we will use two pumps in series so that the flow rate can still be the same means and the Total Dynamic Head can be divided by the number of pumps. Now the TDH is taken at 182.511 feet for two pumps while it was 365.022 feet for a single pump.

There are two ways we size a pump's power: The analytical approach (some calculations) with formulas) or the graphic method (which uses pump performance curves).

Analytically the electric power of the pump is given by $P = \frac{Q*g*TDH}{3.6*\eta}$ with P = electric power in watts, Q the flow rate of the pump in m^3/s, g the gravity which is 9.81 m/s^2, TDH in meters, and η the efficiency of the pump (taken here at 0.75).[10]

$$\text{So } P = \frac{71.42*9.81*55.62}{3.6*0.75} = 14432.98\,W$$
$$P = 14432.55\,kW$$

That is the power that consumes one pump. For the two pumps, the power required is 28.87 kW. After finding the power of pumps, other types of equipment can also be calculated according to their need for power.

G. PV panel selection and Array Layout

A PV module consists of solar cells that convert solar radiation into direct electricity[11]. At a given illumination the current-voltage relation for a solar cell single diode model is given by:

$$I = I_L - I_o\left\{\exp\left(\frac{q}{akT_c}(V+IR_s)\right)-1\right\}-\frac{V+IR_s}{R_{sh}}$$

where I_L is light-generated current, I_o is the diode reverse saturation current, a is the ideality factor which varies from 1 to 5 and indicates solar cell characteristics deviation from ideal behavior, q is the charge of the electron, k is the Boltzmann constant, T_c is the cell temperature, R_s is the series resistance and R_{sh} is the shunt resistance, R_{sh} has a large value and R_s is small so it can be neglected in the analysis.[11]

In order to meet the voltage and amperage requirements of the pump, multiple panels must be wired in series, parallel, or a combination of series and parallel. The total power produced by the panels can be calculated by adding their power outputs. To find the necessary power, panels can be arranged in series, parallel, or mixed configurations.

H. Controller or Inverter

The pump controller optimizes the flow of water pumped in less-than-ideal lighting conditions while safeguarding the pump against high or low-voltage situations. An inverter is an electronic component needed to operate an AC pump. It transforms DC electricity from solar panels into AC electricity.

I. The Delivery Point Pressure

To guarantee that the design flow rate can be supplied to the delivery point(s) at the necessary pressure(s) to operate the valves (such as a float valve), an analysis of the entire design—including the PV panels, pump, pipe, and any storage tanks—must be performed. The goal of this paper was to design the pump's power, but the PVWPS system has a very large design and requires numerous calculations to determine the best design for the solar panel, inverter, and system that determines the necessary water volume.

VIII. CONCLUSION

Due to their use of renewable energy sources, PVWPS plays a significant part in sustainable development. The amount of water needed to meet its needs grows along with the population. It must be used by humanity in a way that doesn't harm the environment. Thus, one of them is the solar-powered pumping system, which offers additional benefits in line with the goals set by numerous nations to prevent climate change and global warming. This essay will assist the people of Nzulo in understanding the role that renewable energy sources can play in a nation with abundant energy resources but a population that lacks access to even water due to a lack of electricity.

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