# Electricity Management Using Maritime Outflow Wastewater Release System

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## ABSTRACT

*Marine outfall is a pipeline system used to discharge industrial or municipal wastewater from wastewater treatment plant to the sea. It is generally discharged under the sea surface. This system uses excess pressure to discharge wastewater offshore, which is a regulation that governs the discharge of any substance to the marine environment. The operation of marine outfall systems makes sense on an environmental perspective, although observing this system in an engineering perspective, significant energy is wasted, as the energy is solely used to discharging water offshore. The focus of this research is to propose an engineering solution to recover the lost kinetic energy and convert it into useful electrical energy. Therefore, the paper starts by presenting a literature review on marine outfall and focuses on the opportunity of using marine outfall systems identified in South Africa where hydropower technology can be used for energy recovery. A proper methodology to conduct the study as well as a system layout have been suggested.*

**Keyword**: - *Energy recovery, Hydropower, Marine outfall ….*

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## 1. INTRODUCTION

Hydropower refers to the process of converting energy from flowing water into electrical energy. This process depends on the kinetic and potential energy of water and is carried out as water rotates the installed hydro-turbine. This movement will convert the energy from the turbine into mechanical energy. The rotating turbine is coupled with the generator's shaft to convert the mechanical energy into useful electrical energy. Hydropower is considered to be the most reliable and flexible type of renewable energy source providing 19 % of the planet's electricity.

**Fig -1:** Marine Wastewater Outfalls and Treatment Systems

It is rated as the most affordable RES, with a long lifespan and low operation and maintenance cost. Between 2004 and 2013, renewable energies increased up to 760 GW and of this 37.5% of the total energy generated were derived from hydropower. Several types of hydropower generation systems such as diversion, impoundment, and pumped storage, and wave, tidal or hydrokinetic systems are currently wide spread. Marine outfalls are pressurized pipeline systems, used to discharge industrial or municipal wastewater from desalination/wastewater treatment plants and the sea surface; usually, they are discharged under the sea surface. Wastewater undergoes treatments before it is discharged to the sea. These are primary treatments, where debris is removed from the wastewater, so as not to damage the treatment system. Secondary treatment, used to remove organic material and suspended solids, further include disinfection, reducing concentrations of bacteria in wastewater and tertiary treatment.

This involves the removal of suspended material, using sand filters, as this treatment is a biological process and chemical precipitation is used to remove harmful chemical substances. Excess pressure is used in the process of discharging wastewater offshore, generally at few kilometers away from the coastal region. For Environmental impact mitigation on the cost, it is preferable that wastewater be discharged far away from the coast. However, in an engineering perspective, the pressure that is used to push wastewater is wasted, since the sole purpose is to push water deep within the sea.

The flow rate is generally measured in the outlet pipe at the end of the treatment process and the density of wastewater is assumed to be close to that of fresh water. The focus of this research is to propose an engineering solution to recover the lost kinetic energy and convert it into useful electrical energy. Therefore, the paper starts by presenting a literature review on marine outfall A proper methodology to conduct the study as well as a system layout have been suggested. The ultimate purpose of this study is to demonstrate the feasibility of this innovative technology given the availability of the resource in South African context.

## 2. LITERATURE REVIEW

The rapid depletion of fossil fuel resources and the need to reduce greenhouse gases (GHGs) emission level have resulted into worldwide concerns. Such concerns have necessitated an urgent exploration for alternative energy sources. More than 80% of world energy supply is still dominated by fossil fuels contributing to climate change. This trend is expected to continue due to population growth leading to rapid growth in fossil fuel power generation. The use of renewable energy sources to meet the daily energy demand is a solution to address such challenges. Allowing consumers to sell renewable energy to the utility grid can cope with the fast-growing electricity demand and thus boost the grid stability. This can also help consumers to reduce their electricity bill costs. To ensure safe and reliable operation micro-grid system, it is necessary to incorporate an energy storage system (ESS) since many electrical utilities tend to allow their electricity prices to differ from time to time. Time of use (TOU) electricity tariff is the common time based pricing mechanism used by many utility companies. The price of electricity is raised during peak hours and then lowered during off-peak hours. Hence, according to the price variation, ESS can allow consumers to store energy during inexpensive period and use it during expensive peak period and/or sell it to the grid. If grid-connected hybrid system consisting of renewable energy sources and ESS is well managed, it will assist consumers to substantially reducing their electricity cost and also increase the reliability of the utility grid. Renewable energy sources such as wind and solar have a drawback of not meeting the demand throughout the day due to their unpredictable nature and random variation. To overcome such drawback, hydrokinetic technology is a Promising solution than can be used in areas with flowing water resource. It is easily predictable since it does not vary rapidly within a very short period of time. However, there are very few studies that have concentrated of modeling and size optimization of the hydrokinetic systems. These studies have revealed the technical and economic benefits offered by hydrokinetic technology. It has proved to offer the most economical and environmentally friendly solutions as compared to solar, wind and diesel generator (DG) systems. However, none of these studies have explored the effect of different load profiles on sizing and operation of hydrokinetic hybrid systems. Furthermore, none of them have considered using the TOU tariff mechanism since they have concentrated on off-grid hydrokinetic systems [1].

Hydropower and climate change show a double relationship. On the one hand, as an important renewable energy resource, hydropower contributes significantly to the avoidance of greenhouse gas (GHG) emissions and to the mitigation of global warming. On the other hand, climate change is likely to alter river discharge, impacting water availability and hydropower generation. Hydropower Contributes significantly to the reduction of GHG emissions and to energy supply security. Compared with conventional coal power plants, hydropower prevents the emission of about 3 GT CO2 per year, which represents about 9% of global annual CO2 emissions. Hydropower projects may also have an enabling role beyond the electricity sector, as a financing instrument for multipurpose reservoirs and as an adaptive measure regarding the impacts of climate change on water resources, because regulated basins with large reservoir capacities are more resilient to water resource changes, less vulnerable to climate change, and act as a storage buffer against climate change. At the global level, the overall impact of climate change on existing hydropower generation may be expected to be small, or even slightly positive. However, there is the possibility of substantial variations across regions and even within countries. In conclusion, the general verdict on hydropower is that it is a cheap and mature technology that contributes significantly to climate change mitigation, and could play an important role in the climate change adaptation of water resource availability. However, careful attention is necessary to mitigate the substantial environmental and social costs. Roughly more than a terawatt of capacity could be added in upcoming decades. Currently, humanity faces the challenge of reaching the new Sustainable Development Goals (SDGs) by 2030. These goals are a sustainable development agenda to guide development actions for the next 15 years. They include 17 goals and 169 targets, and require an annual investment evaluated at 3.3 trillion 4.5 trillion US dollars per year. Energy-related challenges are in Goal 7, which has the aim of ensuring access to affordable, reliable, sustainable, and modern energy for all. Goal 7 has four targets to be met by 2030; this focus mainly on ensuring universal access to energy, increasing the share of renewable energy in the global energy mix, improving energy efficiency, and expanding infrastructure and upgrading technology for supplying modern and sustainable energy. Greenhouse gas (GHG) emissions due to human activity have been altering the energy and climatic patterns of our planet. The main gas involved is carbon dioxide (CO2), which represents 76% of total GHG emissions. These emissions have increased the atmospheric concentration of CO2 from ~277 ppm in 1750 to 397 ppm in 2014, an increment of about 43%. In 2015, CO2 levels registered several peaks over 400 ppm in March and December. In relation to economic activities, the burning of coal, natural gas, and oil for electricity and heat is the largest single source of global GHG emissions [2].

Stability and reliability are main requirements for industrial and domestic power supply. Sometimes, these requirements are not easily achievable due to the remote location of the demand or due to the weak grid supply. Critical loads need to be supplied with power from in-plant generators either to complement the grid or as an emergency source which can tolerate very little or no interruptions. Diesel generators (DGs) are useful in these circumstances because of their simplicity and ease of maintenance. They can be started easily without external supply assistance, available in variety of ratings. DGs can also be integrated with renewable energy sources (RE) such as solar photovoltaic (PV) and wind turbines (WT), making the combination ideal for isolated power generation. Hybrid solar PV–WT–diesel systems present a resolution to the time correlation of intermittent solar source as well as load demand fluctuations. In this configuration, the DG is used to balance the deficit of the power supply from the renewable sources and the battery system when the load demand is high. This combination enhances the efficiency and the output capability of the entire hybrid system. Energy storages are one of the few responses to the integration with variable energy production due to the fluctuation of their resources. Storage system can decrease the effects of variable output power from renewable energy sources, and assure that power can be reliably dispatched in response to the fluctuating load requirements. the development of models for optimal scheduling and energy management of standalone or grid connected renewable systems is gaining attention as a way to minimize the operation cost of hybrid systems. an optimization model for the operation of a hybrid energy system consisting of a hydrokinetic system, a battery bank and diesel generator is developed. The optimization approach is aimed at minimizing the cost function subject to the availability of water resource, total load energy requirements as well as the diesel generator and the battery operational constraints Based on the potential benefits of decentralized energy sources and storage systems in rural electrification as exposed in the different research discussed in the sections above, the combination of hybrid renewable energy systems with PHS is proposed in the present study. This arrangement can be seen as an attractive and interesting alternative for isolated power generation and storage problems with several benefits such as lowered cost of energy produced; lowered environmental impacts and increased reliability and availability of the electrical power supply [3].

Energy is the life blood of world wide economic and social development. When considering the current status of global energy shortages, the emphasis to reduceCO2 emissions, development of alternative energy generation methods and growing energy consumption ,it is clear that there is a need to change the way energy is created and used. The demand for energy increases continuously and those demands need to be met in order to stimulate world wide development. Fossil fuels contribute a large majority of global energy, but due to the dangers of global environment a limp acts, the expansion of fossil fuel as an energy source is in some cases resisted. This forces our current generation to focus on the development of renewable energy sources. Hydro power contributes only 3% of global energy consumption which is only a fraction of its potential. Africa is the most under developed continent with regard to hydro power generation with only 6% of the estimated potential exploited. This should not be seen as a burden, but rather a san opportunity [4].

The growth of climate change and electrical demand as well as rising diesel fuel prices are the key subjects encouraging the use of renewable technologies. Utilization of electrical energy plays an important role in economic growth and improvement of people's living standards. An ideal energy source should be renewable and should have minimal effect on environment. It has been proved that one-third of the world's population does not have access to electricity, but does have access to moving water. Majority of rural residents are very poor, with low living standards, limited education and little access to information. Despite the efforts in remote area electrification, progress and success rates remain low. Poor planning, lack of research and negligence are some of the factors contributing to the delay of rural electrification deployment. To improve the living conditions of rural residents, provision of electricity is crucial. Small remote communities of ten require electricity supply for small ads such a slighting, refrigeration, communications etc. . Solution to wards rural electrification is made possible by means of basic approaches/ techniques such as grid-extension, diesel generators or small-scale renewable energy systems. However, grid-extension to rural areas is considered uneconomical by many utility companies, due to the low consumption and poor factors. This is certainly a nun attractive supply option since most rural residents are poor and thus unable to finance electrical services [5].

For a variety of reasons, an outfall structure may lose its resistance, structural capacity, and/or operational capacity. This total or partial loss may take place at different speeds and be temporary or permanent. The project design should thus be able to assure that the structure will be reliable, functional, and operational. Consequently, values or target levels of these attributes should be specified in the project design phase before the structure is actually built. Evidently, the construction and maintenance costs of the outfall as well as its use and exploitation depend on all of these factors. The European Water Framework Directive (WFD, 2000/60/EC) developed the concept of Ecological Quality Status for the assessment of water masses and for the establishment of water quality objectives. The designing of submarine outfalls is not fully contemplated in some countries legislation. In the Portuguese legislation the WWTP are the ones that require an Environmental Impact assessment (EIA) (Decree-Law No.69/2000 of 3 May and Decree-Law No.197/2005 of 8 November). These studies can also be required by the financing entity or within the administrative framework process. Moreover, should be considered: Directive No.2006/7/CE, of the European Parliament and of the Council of 15 February 2006, concerning the management of bathing water quality or other specific local legislation. Submarine outfall projects generally include specifications pertaining to the conception, design, construction, exploitation, maintenance, and repair of the outfall. Nevertheless, they rarely include a systematic assessment of risks. This signifies that the design methods used are essentially deterministic in nature. There is thus an urgent need for a risk management procedure, based on statistical methods that can account for randomness and uncertainty. Such a procedure would incorporate information and data concerning the failure probability outfalls and the possible consequences of a failure. The result would lead to a more cost-efficient project. For constructions such as breakwaters and coastal defence structures, recommendations (e.g. ROM 0.0, 2002) advise the use of probabilistic and optimization techniques and demonstrate how they can be applied (e.g. Burcharth, 2000; Oumeraci et al., 2001; Losada and Benedicto, 2005). For outfall/intake works (Simm and Cruickshank, 1998) presents a checklist of common risks mainly related to the construction phase, whereas (Figueira, 2008) describes examples of risks at the conceptual, design, construction, and operation stages [6].

## 3. METHODOLOGY

Literature related to the marine outfall, hydropower generation and the status of hydropower in South Africa will be reviewed. Inventory wastewater treatment facilities in South Africa and select facility for case study. Data will be collected on the selected marine outfall site, information about length and diameter of the pipe. The amount of water treated, in terms of its flow rate, will be requested from those responsible for that marine outfall site. An appropriate turbine configuration will be selected and sized, based on the water flow rate, diameter of the pipe and power required to be generated, without disturbing the appropriate operation of the marine outfall. Mathematical models will be developed for hydropower generation using MATLAB/SIMULINK software.

The main components to be modelled are: the inlet water, submerged turbine generator set and the control system. The submerged turbine generator set will be situated at the end of the marine outfall pipe. Based on this, a simulation will be conducted to observe the dynamic behavior of power generated, due to possible disturbances such as variable inlet water flow. Perform a case study analysis on selected facility, by gathering information on monthly electric costs; information on hydraulic profile and daily flow; analyse the cost of equipment, maintenance and labor, versus the payback period. Based on the final results, the computation of the amount of energy generated in one day will be conducted. That energy will be linked to the electricity costs and savings. All cost components of this project will be calculated, to calculate the returns on investment for this project Because of the magnitude of this project no prototype will be built. Simulation results will be presented, analyzed and discussed, using actual data from the selected existing case study.

The proposed energy recovery system to be modeled and simulated is presented in Figure 2, whereby the pressure from the effluent in the pipe is collected by a turbine mechanically coupled to a generator.

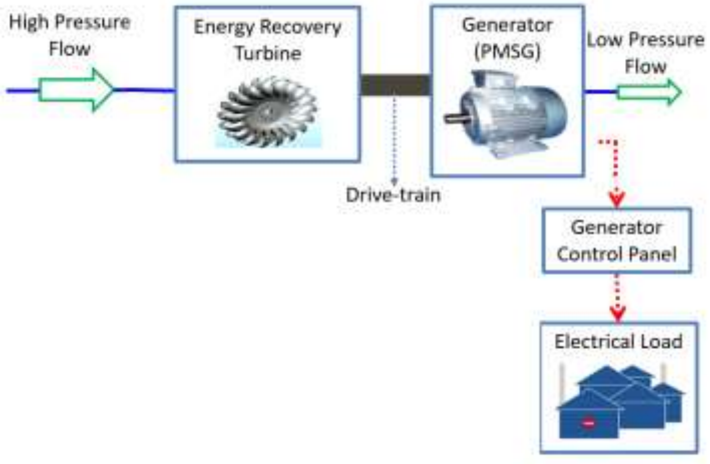

Fig -2: Proposed energy recovery system from marine outfall pressurized effluents

The size of the turbine and generator depend on the amount of energy intended to be recovered from the potential energy available. Due to the nature of products that go through the wastewater treatment plant discharged through the marine outfall, the turbine and generator must be made from materials that are resistant to corrosion.

## 4. CONCLUSIONS

This research looks into the potential usage of marine outfall wastewater discharge systems for electricity generation in South Africa . From the preliminary literature review conducted, it's been revealed that the majority of the research works conducted on the topic were supported the civil and environmental aspects. it's also been revealed that there are almost no works that specialize in aspects like designing, modeling, simulating a system which will recover a number of the energy lost from marine outfalls during the method of discharging wastewater into the ocean and switch it into useful electricity. it had been also shown that South Africa features a significant number of marine outfalls which will be used as potential site, with adequate resources, were the implement energy recovery installation would be possible. The ultimate goal is to form recommendations for hydropower implementation supported the marine outfall flow, head, costs, and payback period in order that facilities are ready to make informed decisions about whether or not the energy recovering installation would be a feasible project and worthwhile investment.

## 5. REFERENCES

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