Electricity Generation through Commercial Water Pipelines

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Abstract- Renewable energy sources are increasingly being utilized for electricity generation as global efforts intensify to reduce dependence on finite and environmentally damaging non-renewable energy resources. Among the various forms of renewable energy, hydropower remains one of the most reliable and mature technologies. Traditionally, hydropower generation has relied on large-scale infrastructure such as dams, which require significant capital investment, extensive environmental assessments, and the availability of geographically suitable sites—typically areas with fast-flowing rivers or high altitudes for water storage. These requirements often present logistical and ecological challenges for both public and private energy generation entities. However, an innovative and sustainable alternative is emerging through the integration of mini-hydropower systems into existing water distribution networks. This approach involves harnessing the kinetic energy of water flowing through commercial and municipal pipelines to generate electricity. By installing compact turbines and generators directly within water mains or outflow systems, it becomes possible to produce a significant amount of energy without the need for large reservoirs or major structural modifications. This method offers multiple advantages. It is cost-effective, relatively simple to implement, and involves minimal environmental disruption compared to traditional hydropower plants. Moreover, it leverages infrastructure that is already in place, such as urban water supply systems, irrigation networks, and industrial pipelines, making it especially suitable for densely populated or infrastructure-rich regions. The generated power can be fed back into the grid or used to meet local energy demands, thereby contributing to grid resilience and reducing the carbon footprint associated with fossil fuel-based electricity generation. The efficiency and reliability of these in-pipe hydropower systems can be further enhanced through the integration of advanced smart control technologies. Just by fixing in front of the pipe a turbine and generator can instantly generate high amount of energy depending upon the flow and speed of the water and turbine, but the advantage that we can get in this type of power generation is that The integration of smart control systems further improves energy efficiency and system reliability These systems monitor water flow, turbine performance, and power output in real-time, optimizing energy generation while ensuring consistent water delivery and system safety. As cities and industries increasingly pursue sustainable development goals, such decentralized, scalable, and eco-friendly power generation solutions are poised to play a significant role in the global energy transition.

I. INTRODUCTION

The concept of generating electricity through commercial water pipelines presents a promising and efficient alternative to conventional hydropower generation methods. Traditional hydropower plants require a range of critical components and site-specific conditions, including a constantly flowing river, large-scale dam construction, advanced water flow control systems, and the installation of turbines and generators. These requirements often lead to high capital costs, extensive environmental assessments, and long construction timelines. However, a more streamlined and cost-effective solution involves installing mini-hydropower systems directly within commercial or municipal water pipeline networks. By strategically positioning a turbine and generator assembly a few kilometers downstream from the water source and integrating it with a commercially laid pipeline, it becomes possible to generate electricity without the need for dam construction or complex water control infrastructure. This setup harnesses the natural pressure and flow of water within the pipes to drive the turbine, thereby converting hydraulic energy into electrical energy in a reliable and sustainable manner. This method not only reduces construction and operational costs but also offers operational flexibility. It can function as a standalone electricity generation unit or act as a supplementary power source during periods when larger power plants undergo scheduled maintenance or unexpected shutdowns. This ensures continuity of power supply and reduces the risk of prolonged outages. The generated power can be routed through dedicated switching systems to nearby substations—whether private or government-operated—for voltage regulation and further transmission to end users. Furthermore, the adaptability of this approach allows it to be seamlessly integrated into existing infrastructure, making it highly suitable for urban and semi-urban settings. It supports the objective of delivering uninterrupted 24/7 power supply to both industrial and residential consumers while contributing to grid stability and enhancing energy security. As a decentralized and environmentally friendly solution, pipeline-based hydropower generation stands out as a valuable component in the broader transition toward sustainable energy systems.

II. LITERATURE REVIEW

Electricity Generation through Commercial Water Pipelines is an innovative and sustainable way and also acts as a cost effective method to generate electricity using hydropower, comparing to a traditional hydropower plant. Traditional large-scale hydropower, which relies on rivers and dams, this method uses existing water infrastructure like municipal water supply lines, irrigation channels, or industrial pipelines to generate electricity. The basic work is simple that when water flows from the dam to then through the pipelines; especially at hilly or high pressure the force of the water flowing through the pipes produces high amount of flow pressure. If a turbine coupled generator is fixed with these pipes, and the high flow pressure (of water) constantly will flow through the turbine will produce a high rotation in the turbine and generator leading to a high and stable voltage output. Additionally these type of system can help in managing the water pressure especially when the level of water increases in the dams and extra water has to be dispensed from the dam reducing/avoiding any kind of destruction in the dam.

III. METHODOLOGY

First, a suitable section of the water pipeline needs to be selected based on criteria such as consistent flow rate, sufficient pressure head, and accessibility. Parameters including Diameter of Pipe, Flow Rate, needs to be measured; also type of turbine, type of generator and size and the source of water to determine the potential energy available for the generation. Through the explained method below this is how the power plant can be constructed through an MIDC ((Maharashtra Industrial Development Co-operation) water pipeline. First the diameter of the pipe is measured which is used in the MIDC pipeline. Diameters of the water pipeline vary according to the type of water distribution lines.

Small Distribution Lines: Typically range from 100mm (0.1m) to 300mm (0.3m)

Medium Distribution Lines: Often range from 350mm (0.35m) to 600mm (0.6m)

Large Transmission Mains: Can range from 700mm (0.7m) to over 1200mm (1.2m).

Let's assume we take a Large Transmission Mains which is 1.2m. So we will have to measure the flow rate of the water in it.

To calculate the flow rate of water through a 1200 mm (1.2 m) diameter MIDC water pipe, you need to know the velocity of water in the pipe.

The flow rate

$Q = A \times V$

Q = Flow rate (m^3/s)

A= Cross-sectional area of the pipe (m^2)

V = Velocity of water (m/s)

Before the above calculations the cross-sectional area of the circular pipe will have to be calculated.

$$A = \frac{\pi D2}{4}$$

$$A = \frac{\pi \times (1.2)2}{4}$$

$$A = \frac{\pi \times 1.44}{4}$$

$$\approx \underline{1.13 m^2}$$

Hence cross-sectional area of the circular pipe is ≈1.13 m2

In large water mains like these, the water velocity ranges from 1.5 to 3.0 m/s, depending on the pressure and the specific industrial requirements. Now to calculate flow rate

Let's assume we take 3.0m/s water velocity.

So for 3.0 m/s:

Q=1.13m^2×3.0m/s = 3.39m^3/s ≈ 3390 L/s

Hence Q ≈ 3390 L/s (Liters per Second)

So as we have the criteria's of the Diameter of the Pipe, Cross-sectional Area, Velocity of water and Flow rate. So after the calculation the type of turbine and generators has to be decided. In most hydropower plants, Kaplan Turbine, Francis Turbine and Pelton Turbine are mostly used but the most effective turbine in a 1.2m pipe will be is Francis Turbine.

Next comes the type of generator. Mostly in India 3 phase synchronous generator is used which has a speed of 1500 RPM and Frequency of 50Hz but the power output depends upon the hydraulic power available hence, generator rating will have to be calculated (assuming factors below)

P= ρ × g × Q × H × η

ρ = Water density (1000 kg/m³)

g = Gravitational acceleration (9.81 m/s²)

Q = Flow rate 3.39 m³/s (≈ 3390 L/s)

H = Effective head (choose based on site)

η= Efficiency (typically 90-95% for Francis turbines)

P=1000 × 9.81 × 3390 × 30 × 0.90 ≈ 897.1MW

So rounding up a 1MW generator can be used.

Next we have to find out how much a 1MW generator can generate electricity in 1 hour.

Energy Produced in 1 Hour:

Power (P) = 1,000 kW

Time (t) = 1 hour

Energy (E) = P× t

= 1000 kW ×1 hour

=1000 kWh

Next Voltage and Current Relationship

The voltage (V) and current (I) depend on the power factor and the output voltage rating of the generator. For a 3-phase AC generator:

P= √3 × V × I × Power Factor

Typical Generator Voltage: 400V to 11kV (depends on design)

Typical Power Factor: 0.8 to 1.0

Example for a 400V, 3-Phase Generator:

Assume:

Voltage (V) = 400V

Power Factor (PF) = 1

Rearranging the equation voltage and current relationship

$$I= \frac{P}{\sqrt{3}\ x\ V\ x\ PF}$$

$$I = \frac{1000}{\sqrt{3}\ x\ 400\ x\ 1} = 1.44 \text{ A}$$

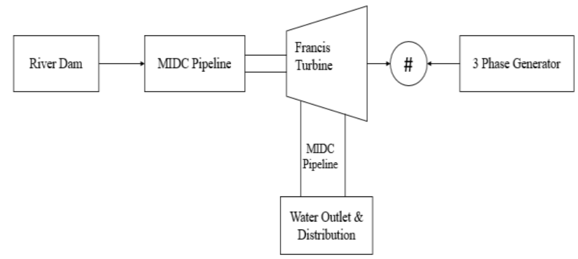
I = 1.44 A

If Voltage (V) = 11kv

$$I = \frac{1000}{\sqrt{3}\ x\ 11kv\ x\ 1} = 52.5 \text{ A}$$

I = 52.5 A

Hence depending upon application i.e. if a long distance needs to be covered an 11kv generator can be used or if a small or limited distance needs to be covered a 400v generator can be used.



Block Diagram of Electricity Generation through Commercial Water Pipelines

As shown in the above block diagram this is the basic method of how generation using commercial water pipeline can be constructed. If the criteria of the water flown from the dam to the pipe is met with high flow rate, after 2-5kms a turbine and generator can be fixed with the pipe and a power plant(power generation) can be started there, with constant water flowing through the turbine and then through the water outlet and distribution.

This method of Electricity Generation through Commercial Water Pipelines can be done in in three ways

1) (G-C) - Generation to Consumer

2)(G-T-S-T-D-C)-Generation-Transmission-Substation- Transmission- Substation- Distribution-Consumers

3)(PhCoSwG-T-S-T-D-C) – Phase Change over Switch Generation– Transmission – Substation - Transmission- Distribution – Consumers

1) (G-C)- Generation to Consumer

This method of power generation is small and can cover a limited area. This can mostly be used for 1 consumer or a small area (village) and is only preferred if there is a pipeline near consumers residential area or the small area/limited area which has to be supplied electricity. The setup is mostly small. The size of the turbine and generator also will be medium comparing to the large sized turbine and generators as shown in the picture.

FRANCIS TURBINE (Medium Size)

MEDIUM SIZE GENERATOR COUPLED WITH FRANCIS TURBINE

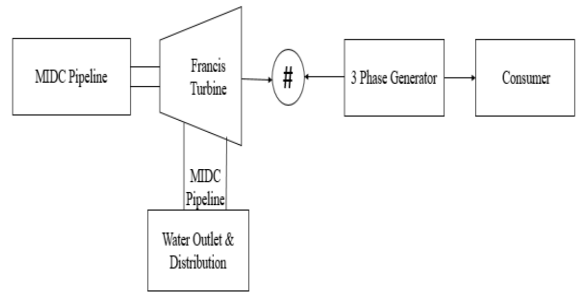
These setup of this type of generation can come in two types given below:-

Type 1)If it is a single consumer there can be only the pipeline, turbine, generator and consumer.

Type 2)If supplying a small/limited area(village) there can be only the pipeline, turbine, generator, distribution(if high voltage needs to be reduced and then distributed) and consumers.

The only drawbacks will be is that the approval of erecting and building the power plant, noise of the turbine after certain periods in use and the safety of the consumer during the actual working.

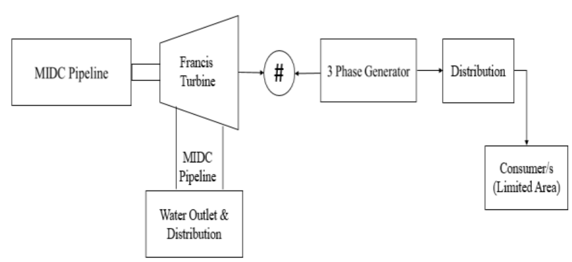
Type 1)For a single consumer



Generation to Consumer
Type 1) For single consumer

As shown in the above diagram this type of generation can only be used for a single consumer. There is an MIDC pipeline, turbine, 3 phase generator and consumer. As the turbine is fixed with the pipeline directly the generator can rotate according to the speed of the turbine. From the turbine output the continuing MIDC pipeline can be fixed which will later go to outlets and distributions. As the turbine will rotate according to the force and speed of the water the generator output voltage rating will have to be 440V, 50Hz with neutral (N) if it is used for a single residential consumer only.

Type 2)For supplying a small/limited area



Generation to Consumer/s
Type 2) If supplying a small/limited area

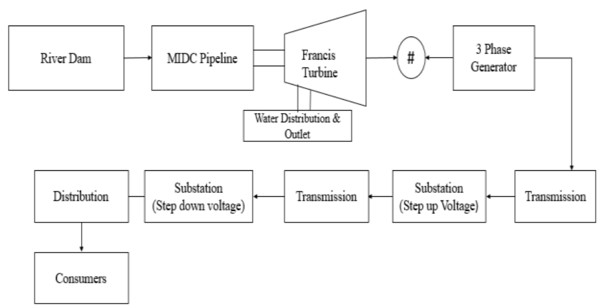
As shown the given diagram above this type of generation can only be used for covering a small/limited area i.e. upto 1-2kms. There is an MIDC pipeline, turbine, 3 phase generator, distribution and consumer/s but here an additional point is that the voltage rating of the generator will have to be increased as 440V, 50Hz 3 phase will not be enough to supply directly to a small/limited area, the generators output voltage can be up to 11KV, 50Hz depending upon the area limit and number of consumers. In the process of generation as the turbine is fixed with the pipeline directly the generator can rotate according to the speed of the turbine continuing; then the MIDC pipeline can be fixed at the output of the turbine which will later go to outlets and distributions. As the turbine will rotate according to the force and speed of the water the generator output voltage rating will have to be 11 KV, 50Hz with neutral (N) if it is used for a small/limited area consumer/s only. The distribution is added only to keep the voltage in a fixed or stepped down value (with a step-down transformer 11KV/440V connected to the distribution) depending upon the number or consumers as if directly 11KV input given to distribution and then to consumer can be dangerous, hence a distribution added can help in keeping the voltage lowered and stable when supplying a limited area.

2)(G-T-S-T-D-C)-Generation-Transmission-Substation- Transmission- Substation- Distribution-Consumers

This type/method of generation is just like the common power plant/generation done in common hydropower plants, only difference is that the generation plant is erected near a pipeline and later to the basic transmission and distribution systems. Here the turbine is fixed with the pipe which continues after the dam. The turbine can be fixed 1 or 2kms away from the dam, the size of the turbine and generator will be greater as this will be just like a regular power plant for generating electricity.

As shown in the given pictures even if there are more than one pipelines, the turbine can be fixed at the any one side corner of the pipeline and the outlet continuing to the distribution etc.

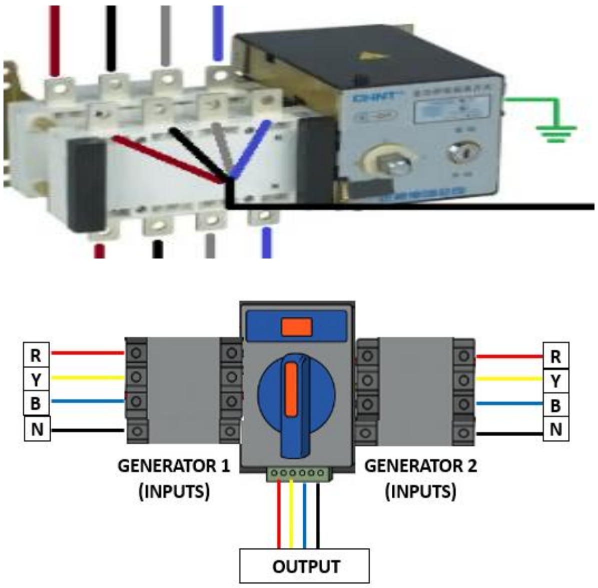
The turbine and generator will have to be be of a more larger size and the generator output voltage will have to be of be of greater voltage of 11-33KV, next it will get into transmission- substation (step-up-voltage)-transmission- substation(step-down-voltage)-distribution and consumers as shown in the diagram.



(G-T-S-T-D-C)-Generation-Transmission-Substation- Transmission-Substation- Distribution- Consumers

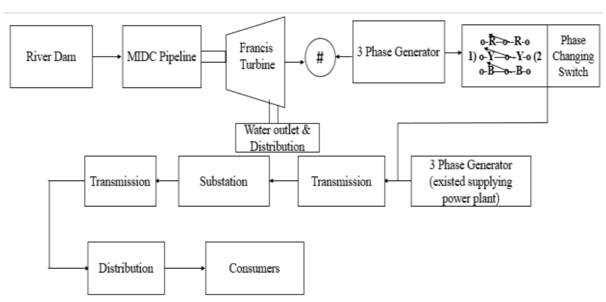
3)(PhCoSwG-T-S-T--D-C) – Phase Change over Switch Generation– Transmission – Substation – Transmission - Distribution – Consumers

This type of generation method is very different comparing to the above two methods. In this method 2 power plants are used 1- Through Commercial Water Pipeline 2- Existing power plant (hydro/ nuclear/ thermal/ solar). The difference in this system is that there are two power plants and there is a phase changing switch (also known as phase changeover or transfer switch)



Phase Changeover Switch

As shown in the diagram above; here it means that there is an already an existing power plant (Generator1 INPUTS) (it can be 2 commercials or a different power plant) which is constantly supplying power and other which is the power plant through commercial pipelines (Generator2 INPUTS) where the switch is connected between the output, only difference is that the commercial water pipeline power plant generator keeps generating power but is not transferring power to the substation until the switch is changed to GENERATOR 2. Now here they can be used in cases such as normal generating and supply power and second, this is a little different.



(PhCoSwG-T-S-T-D-C) – Phase Change over Switch Generation– Transmission – Substation – Transmission - Distribution – Consumers

As shown in the above diagram there are 2 generators and the Phase Changeover Switch. So if the existed supplying power plant has shut down or had to be shut down due to any emergencies or maintenance, the phase changeover switch can be changed to the commercial water pipeline power plant generator (GENERATOR 2), only factors to be met are the voltage, power etc. With this type of system there can be constant supply of power especially for industrial purposes where electricity is constantly necessary. So the existing supplying power plant can only pay for that particular period of the GENERATOR 2 used (if not of their own i.e. a separate power plant) through this there will be no shortage of power and there will be constant supply of power.

IV. RESULTS

The various pipeline-based power generation methods demonstrates a clear distinction in their functionality, efficiency, and scope of application. The G-C (Generation to Consumer) method proved to be most effective for limited-scale electricity needs, such as for a single residential user or a small village. Results show that when the turbine is directly coupled with the pipeline and generator, the system can efficiently produce stable voltage outputs, particularly 440V for single users and up to 11kV for small communities. The compact setup ensures minimal transmission losses and quick installation but is highly dependent on the availability of nearby pipeline infrastructure. In contrast, the G-T-S-T-D-C system, modeled on traditional hydroelectric power plants, supports much higher voltage generation (11–33kV), suitable for larger distribution zones. It includes multiple substations for voltage regulation, which helps maintain grid stability over long distances. The efficiency of this model increases with scale but comes with higher installation and maintenance requirements. The most flexible and resilient model observed is the PhCoSwG-T-S-T-D-C, which includes a changeover switch allowing two generators to operate in alternation. This dual-source system ensures an uninterrupted power supply, especially useful in industrial applications where downtime can be costly. It can be found that switching between power sources through a phase transfer mechanism will provide a smooth transitions and reliable backup during outages. Each system shows a unique strengths—G-C for cost-effective, small-area power, G-T-S-T-D-C for structured and widespread coverage, and the switch-based model for reliability and backup. Overall, the results affirm that the optimal power generation model depends heavily on the scale of use, infrastructure availability, and the need for reliability

CONCLUSION

Electricity Generation through Commercial Water Pipelines, the different methods of power generation using water pipelines reveals a flexible approach to meeting varying energy demands, from individual households to larger communities and industrial setups. The Generation-to-Consumer (G-C) model is ideal for localized, small-scale applications, especially where there is close proximity to a commercial water pipeline. This setup, which relies on medium-sized Francis turbines and generators, provides a direct connection between the generator and the end user, minimizing transmission loss and reducing infrastructure costs. In Type 1, electricity is generated specifically for a single consumer with a standard voltage of 440V, while Type 2 is capable of powering small villages with output voltages as high as 11kV, which are then stepped down via transformers for safe distribution. Although this system is efficient and cost-effective for small areas, it does face limitations such as regulatory challenges, potential noise from turbines, and safety considerations. On the other hand, the G-T-S-T-D-C method mirrors traditional hydroelectric setups, designed for larger regions with high power demands. It uses larger turbines and generator systems capable of producing voltages between 11kV to 33kV, integrating multiple substations for voltage regulation and stability. This makes it suitable for urban or semi-urban applications. Lastly, the Changeover Switch Generation(PhCoSwG-T-S-T-D-C) introduces redundancy and resilience into the power supply system by using two generators — one from an existing plant and another from a commercial water pipeline — connected via a phase changeover switch. This ensures continuous power during emergencies or maintenance periods and is particularly beneficial for industries with zero-tolerance for power outages. Each of these models demonstrates how hydro-based systems can be customized to different scales and needs, reinforcing the potential of decentralized energy generation. By carefully assessing the geographical, technical, and economic factors involved, stakeholders can implement the most suitable model to achieve reliable and efficient energy supply.

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