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Tidal Energy Possibilities and Problems A Study

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ABSTRACT: In order to decrease emission of greenhouse gases, many countries have adopted few policies. So, this paper deals with tidal energy which is the most relevant technologies associated to the sea energy conversion. The key access for the sustainable future of the sea energy are possibility of setting up a related industrial field and adopting government policies based on technological development. This alternative source of energy will prove to be highly efficient with high energy density, provided economical and technical problems are solved. We are living in a world where almost 80% of energy in demand is supplied by sources such as natural gas, coal or oil, which are quickly waning. Tidal power energy is a pollution free energy, having lots of potential. The few studies that have been undertaken till date to identify the environmental impacts of a tidal power scheme have determined that the impacts depend greatly upon local geography. If fossil fuel resources decline during the 21st century, as predicted by Hubbert peak theory, tidal power is one of the alternative sources of energy that has to be developed to satisfy the human demand for energy. Still we have not fully realized its potential, yet the advantages of such kind of renewable energy cannot be denied.

KEYWORDS: Sea Energy, Tidal Energy, Traditional Power Plants, Conventional Power Plants

I. INTRODUCTION

Electricity and heat energy is usually produced from traditional sources of energy such as coal, oil gas and nuclear power. The continuous usage of these fuels is causing various damage to the environment such as climate change, global warming, ozone layer destruction, etc. An efficient power generation technology must be environment friendly, mechanically sound and economical. Tidal power is totally free to use, pollution free and produces no waste. But it might be risky to experiment with unproven technologies involved with tidal energy. China has built the most tidal power stations in the world.

The sea energy available is enormous. The possible sea energy sources are divided into three main groups:-

- Tidal Energy: Making use of the potential energy of different sea levels created by the tidal effect or by using directly the energy of the tidal streams.
- Wave Energy: It is mainly caused by the wind effect on sea.
- Ocean Thermal Energy: This energy is harnessed by using a thermodynamic cycle between the differential temperatures of the deep ocean and surface water

La Rance (France) tidal power plant has been generating energy for last 40 years. Other kinds of sea energy are being tested, apart from tidal energy.

II.TIDAL ENERGY

The tidal energy is the energy stored by the ocean due to the tides produced by the combination of the following effects:

- The gravitational effect of the Sun and the Moon: Tides are caused by the gravitational pull of the moon on the oceans of the world. The sun also plays a minor role in the form of its gravitational pull, which also exerts a small effect on tidal rhythms.

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- The Earth's Rotation**:** Rotation of the earth is also one of the factors in production of tides. The oceans tend to rise and fall as the earth is spinning, processing, and pulsating together with its surrounding heavenly bodies in an ever changing and infinite series of movements.

- Other factors such as different ocean depths at different places, odd shapes of the continent, Earth tilt, etc. Tidal ranges vary from as small as 6 inches to as large as 60 feet. Largest tidal ranges are created at broad-mouthed estuaries and long straight coastlines have the smallest tidal ranges. The available power (per unit area) depends on square of the tidal range. Thus the areas having the largest tidal ranges are the most attractive ones for tidal power generation.

III.HISTORY

Tidal energy is one of the oldest forms of energy used by human beings. Tides can be considered as the longest sea waves, having high periods of 12 to 24 hours and its wavelengths are comparable to the length of circumference of earth's equator. Tide mills consisted of a storage pond, filled by incoming tide which will be passed through a sluice (a channel or passage through which water can flow) and emptied during the outgoing tide through a water wheel. The tides rotate these waterwheels, producing mechanical power to crush grain and this power was available for about two to three hours, usually twice a day.

A.HOW IT WORKS

The rise and fall of sea level can power electric generating equipments. The gearing of such equipments is tremendous to trun the very slow motion of the tide into enough displacement to produce energy. Turbines are used to extract energy from the rise and fall of tides, located in water passages in the barrages. These tidal barrages are built across estuaries. The potential energy is developed due to the difference in water level across the barrages and is converted to kinetic energy, in the form of fast moving water passing through the devices. This in turn is converted into rotational kinetic energy by the blades of turbine. The electricity is thus produced by driving the rotating turbine to a generator.
The output achieved from hydroelectric turbines is maximum when operating at maximum available head. The available head is highest at extreme low tide and extreme high tide. A 3 hour generation period is achieved twice per tidal cycle. Thus for half of each tidal cycle, one can generate at optimum levelseffectively.

IV. TIDAL POWER TECHNOLOGY

A. BARRAGE OR DAM

Tidal barrage is a dam-like structure used to capture the energy from masses of water moving in and out of a bay or river due to tidal forces. It is typically used to convert tidal energy into electricity by forcing the water through turbines, activating a generator. Turbines, sluice gates and, usually, slip locks, arethe basic components of a barrage. All these are linked to the shore with embankments. Instead of damming water on one side like a conventional dam, a tidal barrage first allows water to flow into a bay or river during high tide, and releasing the water back during low tide. This is done by measuring the tidal flow and controlling the sluice gates at key times of the tidal cycle. The sluice gates are opened in response to the adequate difference in level of the water on opposite sides of the barrage. Turbines are then placed at these sluices to capture the energy as the water flows in and out. Then generators are activated by the turbines to produce electricity.

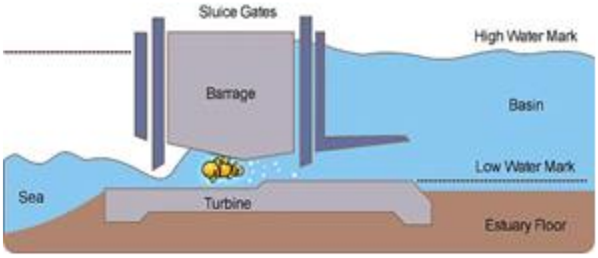

Fig 1.1: Tidal barrage

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B. TIDAL FENCE

Tidal fences typically comprises of a bank of energy conversion devices housed in a continuous structure. This could be a complete barrier across an estuary or a partial barrier to allow access to shipping; it might also be a pier extending from one bank. Theylook like giant turnstiles .The turnstiles spin via tidal currents typically of coastal waters. Crucially, a small head difference is created as a result of the constricted flow through the fence, which, in turn, raises the velocity of the water passing through the generating device. Some of the tidal currents run at 5.6–9 miles per hour (5–8 knots) and generate as much energy as winds of much higher velocity. As seawater has a much higher density than air, ocean currents carry significantly more energy than air currents (wind).Tidal fences are composed of individual, vertical axis turbines which are mounted within the fence structure, known as a caisson, and they can be thought of as giant turn styles which completely block a channel, forcing all of the water through them.
Tidal fences unlike barrage tidal power plants can be used in unconfined basins such as in the channel between the mainland and the nearby off shore island, or in between two islands. Tidal fences are much favored as it does not require flooding of the basin, thus have lesser impact on environment and are significantly cheaper to install. Added to these tidal fences have an advantage of being able to generate electricity once when the initial modules are installed, rather than the complete installation as in the case of barrage technologies. Tidal fences still pose environmental consequences as a cassion structure is required. This can disrupt the movements of large, marine animals and shipping.
For use in tidal barrages various types of tidal turbines are available.

C. TIDAL TURBINE

Tidal turbines are very much like underwater windmills except the rotors are driven by consistent, fast-moving currents. The submerged rotors harness the power of the marine currents to drive generators, which in turn produce electricity. Water is 832 times denser than air and consequently tidal turbine rotors can be much smaller than wind turbine rotors thus they can be deployed much closer and together, still generates equivalent amounts of electricity.

Optimum performance of tidal turbines are obtained where coastal currents run at the speed of 4 to 5.5 meter per hours(3.6 to 4.9 knots).In currents having such a speed, a 15-meter(49.2-feet) diameter tidal turbine can generate as much energy as a 60-meter (197-feet) diameter wind turbine. Ideal locations for tidal farms are close to shore in water depths of 20-30 meters (65.5-98.5) feet.

1)BULB TURBINES

A bulb turbine is one in which water flows around the turbine. The maintenance of bulb turbines is time consuming and may lead to loss of generation as it requires stopping of water for a while. The La Rance tidal plant near St Malo on the Brittany coast uses a bulb turbine.

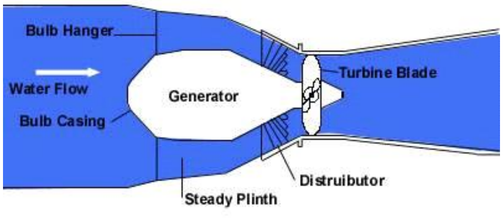

Fig1.3: Bulb turbine

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2) RIM TURBINES

Generators are mounted at right angles when rim turbines are used. Such turbines are not suitable for pumping and also it is difficult to regulate its performance. Straflo turbine used at Annapolis Royal in Nova Scotia is a rim turbine.

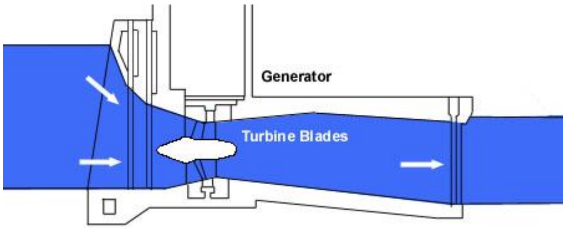

Fig1.4: Rim turbine

3) TUBULAR TURBINES

In tubular turbines the blades are connected to long shaft and these are oriented at an angle so that the generator can be mounted on the top of the barrage. The progress in this technology has been halted by the environmental and ecological impacts of tidal barrages. There are only a few commercially operating tidal power plants operating in the world and La Rance barrage in France is one among them. Tubular turbines were proposed to be used for UK's most promising site, The Severn Estuary.

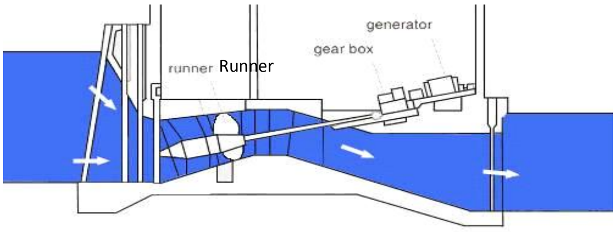

Fig. 1.5: Tubular turbine

D. CATEGORY OF GENERATION

1.EBB GENERATION

In ebb generation, until high tide the basin is filled through sluices and freewheeling turbines. The sluice gates and turbine gates are closed. To create sufficient head across the barrage the gates are kept closed until the sea level falls. The turbines then generate until the head is low again. Then the sluice gates are opened, turbines aredisconnected and the basin is filled again. The cycle repeats itself. Ebb generation, also known as outflow generation takes its name because generation occurs as the tide ebbs.

2,FLOOD GENERATION

In this type the basin is emptied through sluices and turbines generate at tide flood. Flood generation is less efficient than ebb generation as it occurs in the lower half of the basin where the volume of water contained is lesser. Ebb generation occurs in the upper half of the basin (where volume of water is greater.

4.TWO-WAY GENERATION

Generation occurs as both tide ebbs and floods in two-way generation. In general this mode is less efficient as it uses turbines that are designed to generate in both directions.

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5.PUMPING

Excess energy in the grid can be used to power the turbine in reverse so that the water level in the basin increases during high tide (for Ebb generation and two-way generation). This energy is returned during generation.

6.TWO-BASIN SCHEMES

In this scheme there are two basins, one is filled at high tide and the other is emptied at low tide. Between the basins the turbines are placed. The main advantage of this scheme is that generation time can be adjusted with high flexibility, i.e. almost continuous generation is possible. However two-basin schemes are very expensive to construct in normal estuarine situations, due to the cost of the extra length.

V. TIDAL POWER PLANTS

Considering the different ways of using tidal energy, the technologies are classified in the following way:-

A. TRADITIONAL TIDAL POWER PLANTS

Initially tidal energy was used by storing water during high tide for a later use such as to use its potential energy to move till wheels. Later on the potential energy of stored water was used for powering a bulb turbine, generating electricity. These systems are considered as the first generation tidal power plants.

In traditional tidal power plants reversible turbines are usually installed and these turbines makes use of streams of both tides (high and low).Higher the difference between sea levels during high and low tides, higher is the energy produced. Nowadays, five meters is considered the minimum difference needed to produce commercial electricity. The theoretical energy available in a tidal cycle depends on the square of the maximum tide amplitude and on the reservoir area.

Some examples of this kind of installations are:

- Kislaya power plant (Kislogubskaya), located on the White Sea in Russia .It started working as a pilot plant in 1968 and it uses a 0.4 MW bulb turbine.
- On the east cost of Canada, a power plant is located at the estuary of the Annapolis River on the Bay of Funday. 18MW Straflo turbine is used here.

There are only a few places in the world with enough tide amplitude as shown in table I.

Table I

Suitable places for installation of tidal power plants

Country	Place	Tide average height (m)	Estimated Power (MW)	Estimated Generation GWh/year
Argentina	Rio Gallegos	7,5	1900	
Australia	Walcott Inlet	7	2800	
Canada	Cobequid	12,4	5338	14000
Russia	Penzhinsk	11,4	87400	190000
USA	Turnagain Arm	7,5	6500	16600
India	Khambat Gulf	6,8	7000	15000
UK	Severn	7	8640	17000
Korea	Garolim	4,7	400	

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B.TIDAL STREAMS POWER PLANTS

These are the second generation systems in tidal power generation. The main advancement in this system is that it does not require large dams or barrages to collect water. The world's available tidal stream energy is estimated at 5 TW approximately the world energy demand. The high predictability of the sea streams and high load factor of these installations (20-60%) are the most important positive factors if this system that are to be noted.

The available power in tidal streams can approximately be obtained from the following expression

$$P_{tma} = \frac{1}{2} . \rho . v^3 . A$$

Where:

- P_{tma}= Total mean annualized power (W).
- V = Cube root of the mean of the cube speeds (m/s).
- ρ = Current water density (kg/m^3).
- A = Cross-sectional area (m^2).

As there are possibilities for environmental damage, due to the extraction of all the available stream power, it is necessary to use a factor that expresses the usable power percentage with apparently no damaging consequences. This factor is called Significant Impact Factor (SHF) and it is considered as 20% by Black and Veatch a British consultant company.

$$P_{Asite} = \frac{1}{2} . \rho . V^3 . A . SIF$$

VI. ENERGY CONVERSION SYSTEM

Four tidal stream energy conversion systems are proposed for the present scenario:-

A. HORIZONTAL-AXIS TURBINES

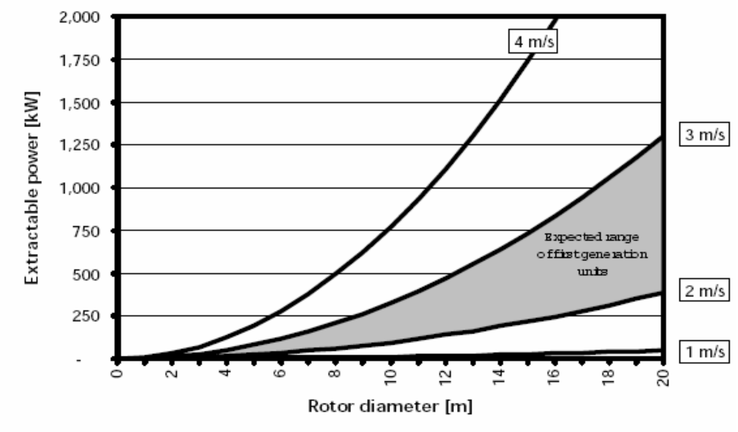

Fig 1.6 Extractable power with a 30% average performance

Such turbines can be either seabed-mounted our may be hanging from floating platforms. They look similar to wind turbines. The rotor diameter and current speed are the factors on which the extractable energy depends(fig 1.6).

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Depending on the stream flow they may have pitch-controlled blades.
Some installations which use horizontal –axis turbines are:

- Seaflow, with rated power of 300kW and 11 m rotor diameter, in Lynmouth, Devon (UK).
- Hammerfest Strom A.S., Norway, with 300kWand 20 m rotor diameters.

B.VERTICAL-AXIS TURBINES

These are similar to vertical-axis wind turbines, where the stream flow is perpendicular to the rotational axis. Initially Darrieus turbines were used. In these turbines the rectilinear blade design produce high efficiency but at the same time it leads to instability of the system due to vibrations. After many researches it was concluded that using helicoid blades (Gorlov turbines) the vibration problem can be solved. Another advantage of Gorlov turbines is that a larger amount of energy can be extracted from tidal streams using it (35%) as compared to Darrieus Turbines (23%).Also Gorlov turbines turn in the same direction regardless of the stream direction, with high versatility in energy conversion.

C. OSCILLATING HYDROPLANE DEVICE

This system is based on the seabed mounted device, Stingray. The main characteristic of this technology is its large wing-like hydroplane, which can be pitch-controlled, oscillating up and downward comprising of oil of a hydraulic power converter.

D. VENTURI EFFECT TIDAL DEVICE

This system comprises of an open venturi tube that uses the venture effect to accelerate the water flow. A pressure reduction is generated in the most constricted point while the water is flowing under atmospheric pressure.

VII. ADVANTAGES OF TIDAL POWER SYSTEMS

The most important advantages of tidal power technologies compared with the other kinds of sea energies are the ones listed below. Some of them are common to both conventional tidal and tidal stream power plants, but other ones only refer to one technology.

A. ADVANTAGES OF CONVENTIONAL POWER PLANTS

- The conventional bulb turbine technology used is far developed with considerable reliability and good performance.
- The high availability of conventional power plants is a positive factor to take into account.
- The low operation and maintenance cost (< 0.5%) and its high availability (>95%), with a high number of generator-turbine groups.
- Extensive experience due to the power plant installed in La Rance (France), which has been working during decades.
- Possible transportation improvement due to its application to the development of traffic or rail bridges across estuaries

B.ADVANTAGES OF TIDAL STREAM POWER PLANTS

- High sea streams energy density. Compared with the most known wind turbines, seawater is 832 times denser than the air. So the power available in a sea current of 14.81 km/h speed is equivalent to a 390 km/h wind one.
- Vertical axis turbines used in tidal streams conversion can be linked to each other in a grid to make better use of the streams energy in deepest areas.

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VIII. DISADVANTAGES OF TIDAL STREAM POWER PLANTS

A. DISADVANTAGES OF CONVENTIONAL POWER PLANTS

- The conventional tidal power plants are far expensive, with very long construction periods, apart from their reduced load factor.
- Nowadays, the environmental impact of conventional tidal power plants is rather high to be assumed.

B. DISADVANTAGES OF TIDAL STREAM POWER PLANTS

- There is an uncertainty about the existing world energy resources related to tidal streams.
- The turbines used for tidal stream energy conversion must be installed offshore and underwater. Consequently, high operation and maintenance costs cannot be avoided.
- Damaging effects, for both migratory sea species and seabed, due to existing underwater cables and anchorages.
- Today’s offshore turbines cost is far higher than the other renewable energies.
- There have been not enough tests to get to know the resistance of these technologies in a sea environment.
- In case of an extended use of this energy conversion, it must be a maximum limit for the extracted energy. Otherwise, the environmental impact could be too high.

IX .REPRESENTATIVE TIDAL PROJECTS OF THE WORLD

A. LA RANCE

The Rance Tidal Power Station is a tidal power station located on the estuary of the Rance River in Brittany, France. Opened in 1966 as the world's first tidal power station, it is currently operated by Électricité de France and was for 45 years the largest tidal power station in the world by installed capacity until the South Korean Sihwa Lake Tidal Power Station surpassed it in 2011.Its 24 turbines reach peak output at 240 megawatts and average 62 megawatts, a capacity factor of approximately 26%. At an annual output of approximately 540 GWh, it supplies 0.012% of the power demand of France.

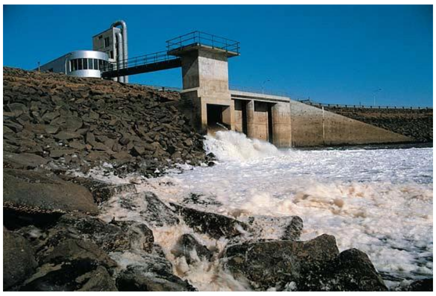

Fig1.7: La Rance Power Plant

The barrage is 750 m (2,461 ft) long, from Brebis point in the west to Briantais point in the east. The power plant portion of the dam is 332.5 m (1,091 ft) long and the tidal basin measures 22.5 km2 (9 sq mi).

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B. ANNAPOLIS ROYAL

The Annapolis Royal Generating Station is a 20 MW tidal power station located on the Annapolis River immediately upstream from the town of Annapolis Royal, Nova Scotia, Canada. It is the only tidal generating station in North America. The generating station harnesses the tidal difference created by the large tides in the Annapolis Basin, a sub-basin of the Bay of Fundy.

Fig 1.7: Annapolis Royal Power Station

C. JIANGXIAPOWER STATION

The Jiangxia Tidal Power Station is the fourth largest tidal power station in the world, located in Wuyantou, Wenling City, Zhejiang Province, and China. Although the proposed design for the facility was 3,000 kW, the current installed capacity is 3,200 kW, generated from one unit of 500 kW, one unit of 600 kW, and three units of 700 kW, totaling the installed capacity to 3,200 kW. Proposals were made to install a sixth 700 kW units, but this has not yet been installed. The facility generates up to 6.5 GWh of power annually.

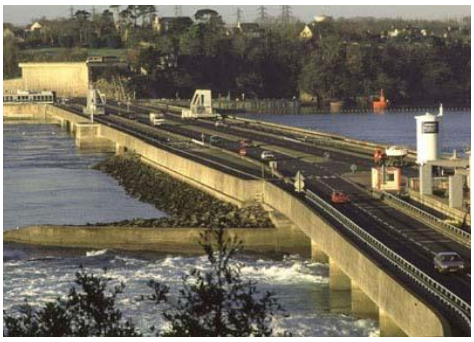

Fig 1.8: Jiangxia Power Station

X. SOCIAL ATTITUDETOTIDAL POWER ENERGY

The social attitude involves the impact on environment, cost factors and efficiency of application. The environmental concern is related to impacts on marine organisms and plants. Some studies have been done to know how tidal power energy leaves an impact on environment and have determined that each specific site is different and the impacts depend largely on local geography. While considering silt and mud deposits, the barrage has a compensating influence on the level of silt and sediments suspended in water. At present the waters in the Severn Estuary carry suspended silt churned by the tides, which does not allow the sunlight to penetrate into the water. Because of barrage, tidal ebbs and flows reduced, removing some of this silt and clearing the water.

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Dealing with financial factors, long construction period for the larger schemes and low load factors results in high expense on energy which increases the capital cost of tidal projects when compared to the usable output with other types of power plant. Unit costs of generation predicted is not expected to change and at present remain uncompetitive with conventional fossil fuels. However, some non-energy advantages from the development of tidal energy cannot be denied.
Tidal power generations use well known and reliable low head hydroelectric generating machine, standard methods to transfer power and conventional techniques for marine construction. The relevant factors in determining the application efficiency of a tidal power plant are:-

- Size (length and height)of the barrage required,
- Difference in height between high and low tides.

As per the high capital costs for tidal energy project, the cost concerning electricity has proved to be sensitive to discount rate. Therefore, we need to prove that the tidal energy is not a waste of money. Public opinion plays a very important role. In countries, some renewable yet costly energy are being used because of public support at large. A bright future can be obtained if we have public knowledge and support and possible threats are researched well.

XIII. CONCLUSION

Tidal energy does not seem to be a big sustainable resource as compared to other renewable energies such as wind and solar energy, yet it is doing a fast rate progress in recent decades. We can see a sustainable future of the tidal power energy, after solving several problems.

- First we need to lower the cost, so that it can be built on a large scale. Hopefully, within six years of operation, the Blue Energy system will generate electricity at a rate of $US 0.04 per KWh.
- Secondly, the turbine needs to be more efficient and the technology related to its working process should be fully developed.
- We should never neglect the impacts of tidal power on our environment, and need to find a way to solve the problems related to it.

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