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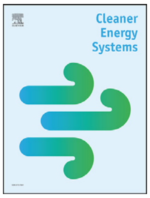

# Tidal energy-path towards sustainable energy: A technical review

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ABSTRACT

The continuous demand for electricity, greenhouse gas emission, and diminution of fossil fuels have led to increased electricity production through renewable energy sources. The challenges of solar and wind energy systems have mostly shown unpredictable nature, so some countries are going towards electricity generation through the tidal energy system. Another advantage of the tidal energy system is that it can be used without requiring lavish grid updates. It demonstrates that increasing the generation duration at the fastest flow velocities while limiting the tidal device's capacity increases the installed system's capacity factor. The economic viability and market competitiveness of tidal energy are also attractive for electricity generation. This paper offers a review of several aspects of the tidal energy system. The assessment is done based on the resource allocation, modeling of the tidal energy system, control system of the tidal energy system, reliability assessment of tidal energy system, and application of optimization techniques in the area of the tidal energy system. Now a day's, reliability assessment is most important to identify the tidal energy system's maintainability, availability and fault rate. This paper also shows future assessment aspects of the tidal energy system and identifies stochastic turbulence, wave speed, sea depth, wave height, and peak wave period directly affecting the tidal current speed and indirectly it effects to the modelling, controlling and reliability mechanism of the system. It is also identifying; optimization technique can have used to find out the optimal value of each parameter of tidal energy system.

## 1. Introduction

Environmental pollution is an essential concern in the current scenario, and lots of pollution is generated through the thermal power plant. Nowadays, everyone wants to adopt electricity generation through the renewable energy system due to the unavailability of conventional energy source and it also create lots of pollution which is very harmful to the sustainable development (Ali 2012). Solar energy, wind energy, are the prominent renewable energy system to minimize the greenhouse gas emissions. Now it is necessary to increase the prospectus of tidal energy systems in the field of electricity generation to go towards the sustainable development (Ahmed 2016). The most effective source is thought to be tidal energy. Through this, the energy from the tides can be utilized to fulfill our yearly demands. However, since its creation, it has not been widely used. But with further study and development, it can serve as a reliable replacement for our energy requirements (Budiyanto 2019). The tidal energy system mainly depends on ocean tides and currents' natural rise and fall. The surge of ocean waters during the fluctuation of tides is used to generate power through the tidal energy system (Elbatran 2015). Tidal energy is a non-conventional energy source that, compared to other renewable energy sources, offers significant benefits in the imminent energy marketplace owing to its high probability (Etemadi 2011). Due to its high power density and excellent predictability, tidal current energy has drawn much attention in the last 10 years from academics and business. Predictability and stability are two significant advantages of tidal current energy over other renewable energy sources such as solar, wind and biomass energy system. The disadvantages of biomass energy system, it creates greenhouse gases, which is harmful to the environment and on the other hand wind energy system are unavailable, when the wind speed is not less than the 2m/s. These traits simplify grid management, lower the price of energy storage, and restrict the use of fossil fuel generators when available renewable energy sources cannot meet the electricity demand. This article comprehensively reviews different assessment factors of the tidal energy system. The objective of this paper to aware the past research about the tidal energy system, because now a day's electricity generation through the tidal energy is very less in all over the world.

Fig. 1 shows the assessment parameters of the tidal energy system. The reason to choose such parameters is that these parameters show the cradle to grave process of the whole tidal energy system. To develop the efficient tidal energy system, which fulfill the load demand, it is necessary to identify a suitable site for a tidal power plant. The assessment of tidal range, tide speed, sea depth, and distance from the load center comes under the resource assessment category. After the proper

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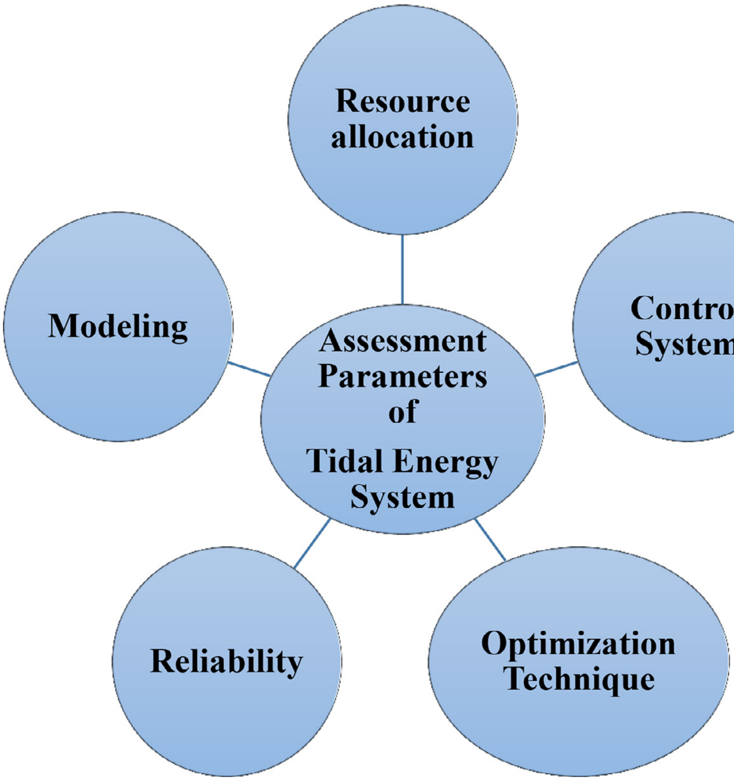

**Fig. 1.** Assessment parameters of tidal energy system.

resource assessment, it is necessary to design a component of the tidal energy system with unit sizing; this is part of the modeling process. The tidal turbine, generator, converter, and battery rating are part of the modeling. After the unit sizing of the component, to identify the desired output to develop the proper control mechanism for the tidal energy system. In the end, reliability analysis is used to measure the tidal energy system's maintainability, availability and fault rate. Optimization techniques are used to measure the optimal value of the given parameter with the help of an objective function.

In the recent scenario, the performance of tidal energy or ocean energy system is enhanced with the use of some advanced technology such as artificial intelligence, data analysis and machine learning. Such type of advanced technology used for prediction, modelling and also create the relationship between different parameter of ocean energy system through the different types of data mining approach. Wimalaratna et al. (2022) describes feasibility analysis of wave energy system in the study area of Australia. Furthermore, this research is enlarged by comparing the main developers in the WE sector to Australia in order to identify some of the contributing factors in other countries that may have led to the expansion of the WE generation in other countries. Finally, some of the identified limitations include a lack of high-resolution data as well as societal and environmental issues. Zhou et al. (2022) describe in the comprehensive way the application of artificial intelligence in the field of ocean energy system. This paper address the limitation of ocean energy system during the generation, transmission and distribution and identify the solution through the artificial intelligence based on the review of several paper on this field. Bakker et al. (2022) describe the concept of artificial intelligence based marine protected area for the electricity generation through the ocean energy system. Digital hardware that gathers data from various sources (such as nano-satellites, drones, environmental sensor networks, digital bioacoustics, marine tags, deep sea UAVs), combined with analytics like machine learning algorithms, computer vision, and ecological informatics techniques, is the foundation of this real-time, mobile, and potentially spatially ubiquitous form of ocean governance. Juan et al. (2022) explained different application of artificial intelligence in the field of ocean energy. The most popular method for resolving issues in ocean and maritime engineering is numerical modelling. However, it has been demonstrated that ANNs are a very good alternative to this conventional strategy and even produce better results, particularly when the problem is random and contains non-linear patterns, thanks to the advancement of machine learning. Messager et al. (2021) explained design and monitoring of ocean energy system by machine learning approach. A clever mix of low-altitude satellites and the high-frequency collected data from geostationary satellites can then be used to extrapolate an ocean surface wind database. Zhang et al. (2022) explained the prediction of wave energy by the Bayesian machine learning. The prediction error of the suggested method, in particular for short-term wave forecasting, is up to 55.4% and 11.7% lower than that of the linear wave theory and deterministic machine learning approaches, and the predictable zone is increased by up to 74.6%. Chen et al. (2021) describe the analysis of wave energy concept through the machine learning approach. In this research, a novel surrogate model that replicates the spatial nearshore wave data calculated by a Simulating Waves Nearshore (SWAN) numerical model is described. Fujiwara et al. (2022) explained the prediction of tidal energy from the machine and deep learning concept. The goal of this paper is to use FFD to predict the design values of tidal/ocean power plants. We are particularly interested in the diffuser's shape's dimensions that correspond to efficient flow-velocity-increasing variables. Jamei et al.(2022) describes the multistage expert system for wave energy forecasting by decomposition based machine learning approach. In order to find the optimal IMFs, lower the computational burden, and improve accuracy, the cross-correlation function's substantial lags at the t-1 and t-2 timescales were applied to the decomposed components and further filtered by the BXGB feature selection. Quian et al. (2022) explained the concept of tidal energy prediction based on hybrid machine learning algorithm. The efficiency of the suggested method is validated using tidal data obtained in Zhejiang province, China, using an acoustic doppler current profiler (ADCP). This paper is categorized into nine sections in which the paper is introduced through Section 1, and Section 2 presents resource allocation and pre-feasibility analysis of the tidal energy system. Modeling and control system of tidal energy system presents in Sections 3 and 4, respectively. Section 5 offers the reliability assessment and application of optimization techniques in the arena of tidal energy systems described in Section 6. Future assessment aspects of the tidal energy system are explained in Section 7. The paper concludes in Section 8, and references are part of section 9.

The novelty of this work, it includes all the concept of tidal energy system such as resource allocation, modelling, controlling, reliability and optimization techniques for the assessment purpose as well as "Outcome" part provide significance of each sub-topic also at the section recent trends and future scope include the possibility of future advancement in the field of tidal energy system.

## 2. Resource allocation of tidal energy system

Tidal power plants always depend on the resource size, basin size, the quantitative value of the tidal range, and various environmental factors. During the resource assessment for the tidal energy system, it is necessary to set the objectives and then collect the data further to identify the sensitivity parameters of the particular locations. To generate sufficient energy from the tidal energy system, water depth should be 30m to 60m. The resource assessment study also focuses on the wave and wind climate conditions to assess the practicability of co-located equipment deployment. Many researchers have already worked on resource assessment of tidal energy systems**.** Marsh et al. (2021) describe a multi-measures estimation of probable sites for tidal energy systems in Australia. Multi-parameter assessment of tidal energy systems is based on the different attributes such as water depth, the value of high and low tides, and finding the suitable location for generating electricity from the tidal energy system. It found three capable spots in Australia, with contiguous portions of 534 km$^2$ in the region north of Broome, Western Australia, 67 km$^2$ in the Banks Strait region northeast of Tasmania, and 1km$^2$ in the Clarence Strait in the Northern Territory. According to the multi-criteria evaluation factor, location stability criteria are given by

$$LS = \sum_{i=1}^{m} w_i y_i \times \prod_{j=1}^{n} T_j \tag{1}$$

Where weighted allotted to the aspect i, $y_i$ is the criterion score for the factor i. Wi is the Boolean constraint. To find out the appropriate energy value, most of the case weighted factors are assigned according to the different factors of the particular location. The figure shows the value of the weighted factor in different circumstances. The value of a weighted function of tidal energy system parameters in Fig. 2. According to the weighted factors, it is found that the distance from the tidal plant to the major power station is the most critical factor, and the coastline and distance from the port are followed them. Distance to the coastline indicates a submarine cable that links the tidal farm to the terrestrial.

Neill et al. (2018) describe tidal energy resource optimization at the level of past and future challenges. Although tidal stream energy has seen a lot of commercial and R&D advancement, the tidal range is a more established technology, with tidal range power facilities dating over 50 years. With the release of the "Hendry Review" in 2017, which looked into the feasibility of tidal lagoon power plants in the U.K., it's a good time to look at tidal range power plants.Khare et al. (2019) explained the pre-feasibility assessment of tidal energy systems. The pre-feasibility analysis includes studying atmospheric conditions, longitude, and latitude, learning of the shoreline area, variability of the tidal current of the projected site, accessibility of tidal energy sources, and a valuation of the probable load and load request on the study area. The pre-feasibility study aids in determining the ideal location for constructing a tidal energy system to meet a specific need. During the resource assessment, it should be necessary to identify the instantaneous power directly proportional to the surface area (a) and square of the water level difference (d) between the upstream and downstream sites.

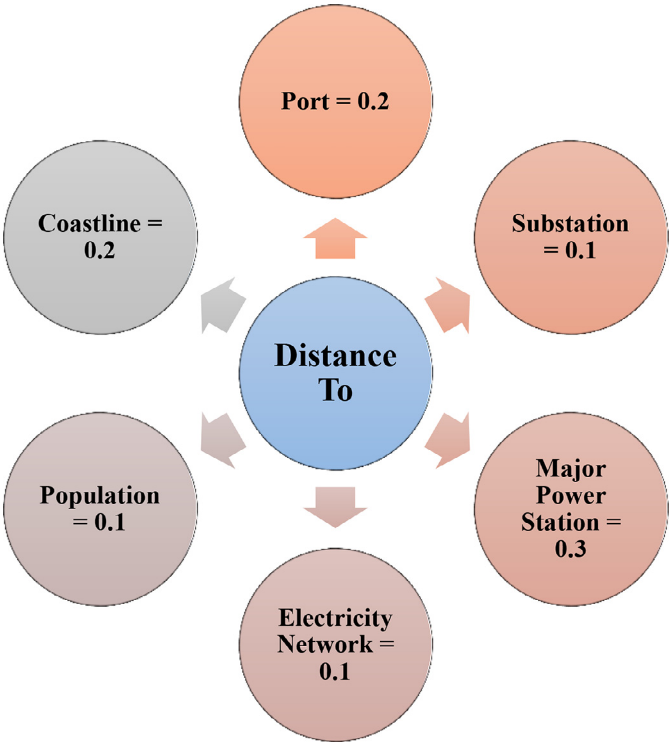

**Fig. 2.** Distance to infrastructure weighted values.

$$P \propto ad^2 \tag{2}$$

The following are the number of areas not included as a basin area for electricity generation, directly and indirectly affecting the generated power capacity.

- Underwater oil and gas pipeline
- Restricted defense areas
- Marine key ecological features
- World heritage areas

Buric et al. (2021) analyzed possible locations at sea strait based on the mathematical equation of tidal current. Most of the resource assessment for the tidal energy system is done based on the value of tidal current. Still, in this article author also analyzed the resource allocation based on the properties of shallow water. Using the high tenacity 3D hydrodynamic model SCHISM, this strait's tidal current energy resource potential was assessed. The model's findings show that tidal current velocities in the strait are up to ten times greater than those in the open sea and vary geographically. Rocha et al. (2020) describe Ria de Aveiro, Portugal, investigating various prospective locations for a viable tidal energy system. This work estimated the tidal potential energy for the Ria de Aveiro lagoon using a model constructed in the Delft3D simulation process. This program can mimic the hydrodynamics of this complex system, and simulations were run to find hot areas for collecting gravitational potential energy. Jiang et al. (2021) discussed probable locations for ideal tidal energy plants in China. With an averaged tidal energy density of more than 400, 900, and 1400 W/m$^2$, respectively and this study revealed 46, 24, and 8 excellent locations suitable for tidal energy extraction and consumption. Using 50-year and 100-year SLR models, the influence of sea-level rise (SLR) on tidal energy distribution in the study region is explored, considering the long development cycle of tidal energy and global climate change. Under 49-year and 99-year SLR models, global means tidal energy increases by 3.0% and 6.50%, respectively. Simonsen et al. (2021) describe the analysis of the potential location for the efficient tidal energy power plant, Faroe

**Table 1**
Summary of resource allocation of tidal energy system.

| Author/Ref. | Objective | Study Area | Outcomes |
|---|---|---|---|
| **Marsh et al. (2021)** | Multi-Criteria evaluation of potential sites | Australia | Promising spot with the portion of 534km2 in the north of Broome, 67km2 Banks strait northeast of Tasmania, 1km2 Northern Territory |
| **Neill et al. (2018)** | Tidal energy resource optimization | U.K. | Promising spot with 100km2 |
| **Khare et al. (2019)** | Feasibility assessment of tidal energy system | India | Gulf of Cambay<br>Gulf of Kutch |
| **Rocha et al.(2020)** | Potential location for tidal energy system | Riade Aveiro | Spot of 50km2 find out in the Riade Aveiro |
| **Jiang et al. (2021)** | Potential location for tidal energy system | China | Identified 46, 24, and 8 prime sites with an average tidal energy density greater than 400, 900, and 1400w/m2. |
| **Simonsen et al. (2021)** | Potential location for tidal energy system | Faroe Shelf | A total of 13 sites have been identified with water depth greater than 40 and peak velocity greater than 2.5 |

Shelf. The energy potential in the tidal streams on the Faroe Shelf is estimated using a barotropic numerical model with a resolution of 100. A total of 13 sites have been identified as potential tidal stream energy harvesting possibilities, with a total available mean energy flow in transects across these locations reaching 2. The lower estimate is for the mean tide, whereas the larger estimate is for the eight evaluated components, all of which had depths greater than 40 feet and peak velocities greater than 2.5. Liu et al. (2021) explained a widespread review of the resource perspective for the tidal energy system. In light of these circumstances, this paper reviews feasible tidal current assessment studies in China, with most prevailing tidal current energy hotspot analyses involved, categorized, and contrasted. These areas of curiosity are further classified according to their exploitability, which is based on theoretical energy resource estimation and local bathymetry, transportation, policy, and other factors. Diaz et al. (2020) analyzed the potential location for a tidal power plant at Minho Estuary. A depiction of tidal constraints in estuaries and their potential for usage in tidal power mining are analyzed. The tidal parameters studied are compared to estuaries worldwide to come up with a list of possible places. The preliminary examination of the site and general features of a tidal test center and tidal farm in the Minho River estuary on the Spanish-Portuguese border is addressed in a case study. Marsh et al. (2021) describe resource assessment for tidal energy systems in Banks Strait, Australia. To determine the location's viability, high-resolution unstructured mesh two-dimensional (2D) models were built using the newly devised COMPAS hydrodynamic model. The model was calibrated and validated using the results of five Acoustic Doppler Current Profiler field datasets. Simulation results indicate that significant tidal energy resources exist, with maximum tidal currents of nearly 3 m/s found at depths suitable for small and large-scale Tidal Energy Converters (TEC) array installations, making this region promising for tidal energy extraction for both on and off-grid energy demands.

**Outcomes:** According to the above discussion, the significant factors for location assessment of tidal energy systems are water depth, the value of low & high tides, climate condition, longitude, latitude, coastal area, tidal current, load demand, and basin area. At the initial level, it is to be done territorial and site evaluation. Table 1 shows the outcomes of the above discussion**.** In the past, research resource assessment was done through an instrument such as a tide gauge, but now a day's prefeasibility assessment or resource assessment is done through the artificial intelligence system. In the recent research, drone-based technology is also used to measure tidal range and sea depth. Data mining and data analysis are also used to predict or forecast tidal energy resources and measure the future load demand for the tidal power plant. Recent research also calculates pre-feasibility parameters through the neural network and fuzzy logic-based system.

## 3. Modeling of tidal energy system

In the tidal energy system, modeling is the approach used to create the practical framework of tidal power plants. It is also a process of optimum design of different components of tidal power plants. Nowadays, many research-based mathematical modeling methods have been conducted to analyze the amount of energy generated from the tidal energy system without considering environmental parameters. The total energy generated from the tidal power plant is given by

$$T_P = \sum_{i=1}^{m} \left( n \times \frac{1}{2} \rho C A \vec{V}^3 \right) \tag{3}$$

Where Tp is the total energy generated from the tidal power plant, 'C' is the turbine thrust coefficient, 'A' is the flow facing area swept by the turbine, 'v' is the velocity vector at hub height and 'n' is the number of turbines.Khare et al. (2019) describe the concept of tidal energy system optimal size and modeling. The correct selection of a system component that can fulfill the load demand cheaply is essential in defining the unit size of a tidal energy system. Wang et al. (2017) describe the influence of tidal energy systems on tidal circulation and the modeling of tidal energy systems. The possibility of collecting tidal energy from Puget Sound's small tidal channels is investigated in this study, which uses a hydrodynamic model to determine the power potential and the influence on tidal circulation. The research site is a multi-inlet bay system with two narrow inlets, Agate Pass and Rich Passage, connecting to Puget Sound's Main Basin. A three-dimensional hydrodynamic model was used to assess the research location for tide heights and currents. Yang et al. (2013) present a tidal channel and bay system connected to the coastal ocean, a numerical modeling analysis of in-stream tidal energy extraction and its effects on hydrodynamics and transport processes. In a three-dimensional (3-D) coastal ocean model, a marine and hydrokinetic (MHK) module was built utilizing the momentum sink technique.

The MHK model was validated using analytical solutions for tidal channels under one-dimensional (1-D) conditions. The modeling of the tidal energy system is done through the 0-D, 1-D, 2-D, and 3-D simulations. Fig. 3 shows the different types of modeling of the tidal energy system. The assessment of the tidal energy system through the 0-D simulation includes neap spring conditions, realistic turbines, sluice gates characteristics to analyze the variable transients, and steady-state flow rates. The variable wetted surface area assessment is also part of 0-D simulations. The 1-D model of the tidal energy system is based on the Saint-Venant equation and is used to analyze the sensitivity parameters of the given geometry of the tidal energy system. 2-D model simulation is based on the shallow water equation to improve the operational assessment of hydrodynamic modeling of tidal energy systems. 2-D simulation is done through the Thetis, and it is a flow solver for simulating coastal and estuarine flows of different tidal ranges. A 3-D simulation is done through the momentum sink approach, and it is used to analyze maximum generated energy and capacity size decline across the channel.

According to the momentum sink approach, generated power through the tidal turbine is given by:

$$F = \frac{1}{2} \frac{DA}{U} |\vec{V}| \vec{V} \tag{4}$$

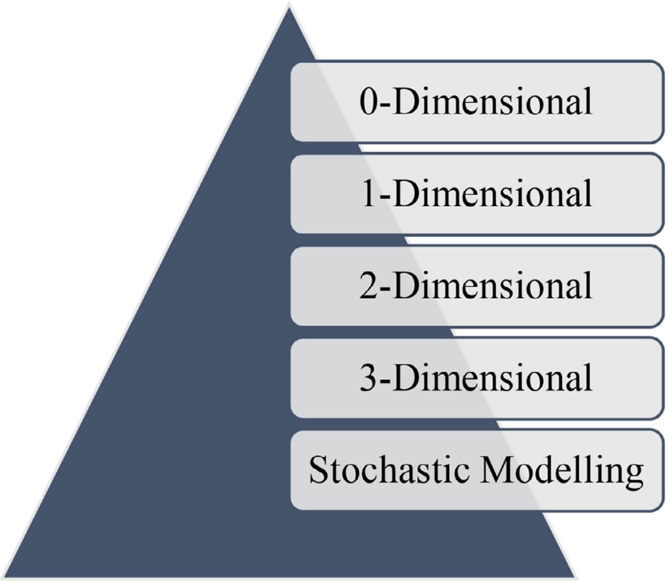

**Fig. 3.** Modelling of tidal energy system.

Where F is the momentum sink rate from a control volume, D is the momentum extraction coefficient, A is the flow facing area of the turbine's pn turbine swept area (m2), and v is the vector velocity (m/s).

The mathematical expression for tidal current speed is given by

$$\begin{aligned} & \textit{Resulting Tidal Current Speed} \\ &\quad = \textit{Stochastic Turbulence} + \textit{Current Speed} \\ &\qquad + \textit{Wave Speed Parameter of Wave Speed} \\ &\quad = \textit{Vertical Distance from the Sea Surface to the Hub Height} \\ &\qquad + \textit{Sea Depth} + \textit{Random Phase} + \textit{Wave Number} \\ &\qquad + \textit{Wave Height} + \textit{Peak Wave Period} \end{aligned} \tag{5}$$

Dong et al. (2021) described a 300 kW horizontal-axis marine current power conversion system with an adaptive variable-pitch turbine and decisive PMSG. The BEMT demonstrates the idea of a propeller with balanced airfoils and rearward swept blades that follow the reversible flow and exhibit hydrodynamic pitching, restarting, energy, and thrust capabilities. Jonsdottir et al. (2020) describe the transient stability of stochastic modeling of tidal energy systems. This article compares the short-term variability of these two green energy sources, wind and tidal, and their impact on the system's dynamic behavior. Stochastic prototypes of the temporary fluctuation of these two green energy sources are projected with this goal in mind. According to simulation data, tidal generating causes bigger frequency changes than wind generation. Xue et al. (2021) describe the evolutionary algorithm model used to model tidal energy systems. One of the essential aspects of tidal range schemes worldwide is choosing the best location and improving the scheme's design and operation to optimize societal needs and energy-generating benefits. Variations in the design parameters of coastal range schemes for power production might lead to a wide range of design and operating situations. Ewing et al. (2020) provide a tidal energy system failure rate framework with a probabilistic failure rate. A sensitivity analysis is utilized to assess essential component design parameters and their impacts on failure rate using a failure rate model for a tidal turbine pitch system, with related uncertainties, based on empirical mechanics of failure equations. The predicted failure rate is then compared to data from many wind turbine failures. Tidal turbines have a failure rate around half that of conventional turbines, although this is unlikely to be acceptable due to high-reliability requirements. Gu et al. (2018) describe the framework of a 120KW tidal power conversion system. The whole design of a full-scale system, including the system design, control concept, and sea testing, is provided. The system design includes the turbocharger, pitch system, hydraulic chain drive, and electrical system. The blade properties, airfoils data, and comprehensive structures of these electromechanical devices are shown. The control concept, which comprises grid-connected voltage stability, and pitch adjustments, is offered based on an analysis of the output power characteristic of the tidal energy system operation. Yosry et al. (2021) describe vertical axis tidal turbines' project and characterization for low-velocity scenarios. The design and evaluation of a tiny vertical axis hydrokinetic turbine system at minimum water velocities is discussed in this paper. The turbine model's blade shape, solidity, and aspect ratio were chosen in order to achieve a self-opening and effective process. With the ranks to ongoing advancements in preservative industrial technology, the model may be exactly created at a fraction of the charge afforded by old-fashioned machining procedures.Khare et al. (2019) explained the scheme and optimization of solar-tidal hybrid renewable power systems. The findings of the article show that a novel optimization approach is needed to predict and examine the performance of a solar–tidal interconnected power system. Among the macro-level efforts is a unique tidal–solar system in Cochin, India's coastal region, and modeling a tidal–solar energy system utilizing the HOMER software programmed? Kuschke et al. (2011) describe the scheme of a tidal energy conversion system for a smart grid. In the situation of the smart grid process, this is critical. Simulation can be a useful tool for analyzing tidal energy conversion systems (TECS) when combined into a smart grid. In this work, two forms of simulation are addressed. The power generating curves are the first type. Power information, for example, is critical for smart grid scheduling. Voltage and current waveforms are the second types. This is crucial when analyzing fault transients, for example. Fahmy et al. (2010) describe mathematical modeling of the tidal energy conversion system in the Red sea area. A tidal system design is given for feeding a limited D.C. load near the shore. As a D.C. load, dc lighting along the beach is chosen. Furthermore, an optimization control issue is resolved in order to run the tidal-producing system at the optimal values of the impacted system parameters. The research is intriguing since it examines a renewable energy source that should be considered because it is both cost-effective and environmentally friendly. Okoli et al. (2017) describe how tidal energy conversion systems are modeled. Using a marine stream mean velocity model, the average current velocity of the Qua Iboe River was determined, and the findings reveal that the river has an average current velocity of 0.79 m/s. The power of a single turbine was modeled in MATLAB/Simulink, and the resultant power was 36.79 KW. The estimated cost per kilowatt-hour was 103.9 nairas. Finally, the Qua Iboe River, which flows north-south to the Atlantic Ocean, has the potential to be a location for tidal current turbines to be installed. Table 2 provide summary of modelling of tidal energy system.

**Outcomes:** The framework of the tidal power system is done through the 0-D, 1-D, 2-D, and 3-D models. The valuation of the tidal energy system through the 0-D simulation includes neap spring conditions, realistic turbines, sluice gates characteristics to analyze the variable transients, and steady-state flow rates. The 1-D model of the tidal energy scheme is centered on the Saint-Venant equation and is used to analyze the sensitivity parameters of the given geometry of the tidal energy system. 2-D model simulation is based on the shallow water equation to improve the operational assessment of hydrodynamic modeling of tidal energy systems. A 3-D simulation is done through the momentum sink approach, and it is used to analyze maximum generated energy and volume flux reduction across the channel.

In the future, it is also possible to design of tidal power plant through the HOMER and HYBRID 2 software. Now a day's internet of thing-based tidal power plants is the key advancement in the field of modeling. The use of IoT-powered solutions to improve and progress the tidal energy sector will have a significant influence as a result. The use of sensors has made it possible to remotely control the energy consumption patterns, simplify applications, and monitor room temperatures in real-time. Data management and the benefits of employing flexible IoT-based systems

**Table 2**
Summary of modelling of tidal energy system.

| Author/Ref. | Objective | Method | Outcome |
|---|---|---|---|
| Khare et al. (2019) | Optimization and modelling | HOMER | Proper unit sizing of component fulfill the load demand cheaply |
| Wang et al. (2017) | Tidal circulation and modelling | Hydrodynamic model | Hydrodynamic model are used to identify power potential & the influence on tidal circulation |
| Yang et al. (2013) | Modelling of tidal channel and bay system | Numerical modelling with momentum sink techniques | Find the optimal value of power generation |
| Xue et al. (2021) | Modelling of tidal energy system | Evolutionary algorithm model | This method is used to optimize societal needs and energy generating benefits |
| Ewing et al. (2020) | Failure rate framework of tidal energy system | Probabilistic failure rate model | Tidal turbine have a failure rate around half that of conventional turbines |
| Gu et al. (2018) | Framework of a 120kw tidal power conversion system | Mathematical modelling | The whole design of a full scale system, including the system design, control concept and sea testing. |

are two major aspects influencing the expansion of IoT in the tidal energy sector. IoT lessens the difficulties and enables management to advance through any problems that may arise.

## 4. Control system of tidal energy system

A control system is a systematic approach that offers anticipated output by adjusting the inputs. In the tidal energy system, different features work in a combined way to measure the desired output. A tidal power plant's control method includes the idea of hydrokinetic energy. The real power that a tidal turbine can extract is used to calculate the intended output is

$$P = \frac{1}{2}\rho C_p(\gamma, \beta)a.U^3 \quad (6)$$

Where $\rho$ is the density of water, Cp is the performance coefficient, and 'a' is the swept range of the tidal turbine rotor, U is the flow velocity. According to the above equation, the output power is controlled by controlling the seawater concentration, blade's swept range, and flow velocity. Lots of researchers already work in the field of the controller of the tidal energy system. Yin et al. (2021) describe the concept of back-stepping disturbance control in tidal energy systems for optimal power extraction. The suggested BDRC is a one-of-a-kind control concept that excels at dealing with significant uncertainty while requiring little information regarding turbine dynamics. To track the ideal tidal turbine speed and hence maintain optimal power output, the BDRC system is split into two circuits: one for turbine dynamics and one for q-axis current dynamics. The stability and convergence of the two closed control loops are tested and confirmed. Omkar et al. (2019) describe the performance assessment of tidal energy systems based on the different control strategies. The performance and similarity of control approaches such as sliding mode controllers and P.I. controllers are investigated in this research using step and bode plot responses. The system has an output voltage range of 0.37 kV to 2.39 kV and is suitable for D.C. micro grids. The performance of HAMCT paired with PMSG and the power converter with a controller is modeled and implemented in the MATLAB/SIMULINK environment. Yin et al. (2018) describe the power control of tidal energy systems based on fuzzy logic. The ideal generator power is then computed using a fuzzy logic tuning approach, with the power converter current and its changes as input variables. The calculated optimal generator power is used as a reference for cascaded control loops to regulate direct power. The efficacy of the recommended control was investigated in MATLAB/Simulink simulations using a 50 kW tidal turbine system with a gear ratio of 2. The test results demonstrate that the proposed fuzzy tuning strategy is viable and that the active generator power can be readily increased while the reactive power is reduced using the proposed direct optimum power management method. Sousounis et al. (2019) describe the utilization of torque pulsation mitigation strategy to identify the effect of a supercapacitor in a tidal energy system. The supercapacitor can withstand quick short-term changes in electrical power while maintaining a stable D.C. connection voltage. Supercapacitors are also being researched for grid connection in weaker grids and in current tidal arrays. According to the findings, installing a supercapacitor at the D.C. link positively influences D.C. link voltage and grid side harmonics. Amirouche et al. (2021) describe sensor-less-oriented and direct power control approaches used to regulate tidal energy conversion systems. A field-oriented control approach is utilized to operate the generator, an extended Kalman filter is used to predict the rotor's speed and position, and the speed is regulated using a fuzzy logic controller. A virtual flux-based direct power control approach is used to regulate a two-level voltage source inverter, and the current is filtered using an LCL filter in the grid side converter. Sahu et al. (2022) describe for frequency stability of a tidal energy-based A.C. micro grid, a DQN optimized tilt fuzzy cascade controller was used. The parameters of the suggested controller are ideally generated utilizing a new deep Q-network (DQN) technique in several working domains. A comparative study was done to verify the applicability of the suggested tilt fuzzy cascade controller in response to frequency regulation of microgrid systems. Finally, the DQN optimized tilt fuzzy cascade controller has shown to be more successful in terms of microgrid frequency regulation. Bickley et al. (1984) explained optimal control of a single-basin tidal power scheme in various operating modes. The control of the scheme is formulated using dynamic programming to maximize its energy production when run in either of these modes: hydrodynamic influences inside the scheme are ignored in the formulation, but real turbine characteristics are employed. For an ebb generation, optimal control was deemed optional, but it is required if the system is to be used in any other mode. Zhen et al. (2015) discuss designing and implementing a pitch control system for a tidal turbine with a horizontal axis. The pitch of tidal turbines must be controlled. A variable pitch control system was developed in this article to adapt to the bi-directional tidal stream and safeguard the turbines. The gadget uses a 32-bit STM32F207 processor with an incremental P.I. control approach as the primary controller to accomplish accurate pitch angle control. In addition, the system implemented feathering control through remote one-click control, significantly improving pitch control dependability. Tsuji et al. (2015) describe the assessment of the tidal energy conversion system through the constant turbine output control system. This analysis was carried out with a continuous stator d-axis current of -0.91 pu in mind. The effect of the stator d-axis current must be taken into account. This research aims to look into this dependency for a DFIG-based tidal current power cohort system. With a constant stator d-axis current, the capacity factor varies. Wang et al. (2018) describe the concept of different controller strategies of tidal power alteration systems. It also covers energy consumption, load control, and storage cell charging and discharging alternation, all of which would be supported by hardware circuit design and software programming. According to the permanent magnet synchronous generator's properties. To certify the steadiness of the power generation system, we implement the necessary control and protection measures. Fig. 4 shows the control strategies of tidal energy systems. Fuzzy logic controls the tidal generator's pitch an-

**Fig. 4.** Control strategies of tidal energy system.

gle and the maximum power point tracking (MPPT) of a tidal generator. An adaptive backstepping controller is suggested to capture the most energy from marine currents. The controller can accurately evaluate and correct for uncertainty and disruption.

Sharaf et al. (2009) describe the concept of a PID dynamic controller for a tidal power adaptation system. PSO is used to operate a TCR+FC scheme that combines a minimum-cost dynamic capacitor compensation DFC with a Static VAR Compensator SVC. The Tidal Wave Energy Conversion Scheme is stabilized using a dynamic self-regulating control mechanism that exploits real-time error (TWEC). The control goal is to track and harvest as much energy as possible from the tidal wave energy system, then transfer that energy efficiency to the isolated local electric load. Choi et al. (2007) explain a novel control mechanism for maximum point tracking for tidal energy systems. With the innovative MPPT(Maximum Power Point Tracking) control strategy given in this study, it is unnecessary to utilize the tidal turbine characteristic at various tidal speeds and monitor the tidal speed or/and the rotation speed of the tidal turbine for a generation. As a result, the finished system is less expensive, more efficient, and simpler. The suggested control mechanism was theoretically investigated and tested using MATLAB Simulink. The duty ratio was also adjusted using the fuzzy controller. Sousounis et al. (2014) explained that long-distance converters regulate tidal energy conversion systems. Variable-speed control strategies that allow the system to operate at its maximum power coefficient can improve generator output. In contrast, long three-phase cables between the generator and onshore voltage source converters can improve availability by reducing the number of off-shore components. A comprehensive resource-to-grid model constructed in MATLAB/Simulink and system analysis for harmonic effects are used to investigate the tidal current energy conversion system. Ghefiri et al. (2017) describe how tidal energy systems may be controlled using MPPT. A rotational speed control based-Maximum Power Point Tracking (MPPT) for a TSG is researched to give the system the proper rotational speed in order to monitor the maximum power and hence keep the pitch angle null. To assess the success of the control technique, two study examples were supplied. The suggested control offers acceptable MPPT reference tracking according to the obtained data. Table 3 shows the summary of control system of tidal energy system.

**Outcomes:** According to the above discussion, it is found out backstopping, sliding mode control, and fuzzy control are the appropriate control system methods for optimal power extraction. The speed of the turbine is controlled by sensor less field-oriented control and direct power control techniques. It is also found that constant turbine output control and PID dynamic error controller are appropriate methods for maximum power point tracking from the tidal energy systems.

## 5. Reliability analysis of tidal energy system

Reliability analysis of tidal energy systems studies measurement scales and studies different components that compose the scales. Several challenges occur in operation and maintenance of tidal energy systems, which is the most significant motive for the sluggish growth of the tidal energy sector. The reliability analysis of tidal energy systems provides information about the parameters which directly or indirectly affect the performance of the overall tidal energy system. Such type of assessment reviews commonalities, success & failure of different engineering issues, availability, maintainability, and disaster rate of various mechanisms of the tidal energy system. Many researchers have already worked in the

**Table 3**
Summary of control system of tidal energy system.

| Author/Ref | Objective | Method | Outcome |
|---|---|---|---|
| Yin et al. (2021) | Control system of tidal energy system | Back stepping disturbance control | To track the ideal tidal turbine speed and hence maintain optimal power output |
| Omkar et al. (2019) | Performance assessment of tidal energy system | Sliding mode controller with MATLAB environment | The system has an output voltage range of 0.37KV to 2.39KV and is suitable to DC micro-grids |
| Yin et al. (2018) | Power control of tidal energy system | Fuzzy logic | Fuzzy tuning strategy is viable and that the active generator power can be readily increased, while the reactive power is reduced using the direct optimum power management control |
| Amirouche et al. (2021) | Regulate the tidal energy conversion system | Sensor less oriented and direct power control | Kalman filter is used to predict the rotor's speed and the position |
| Bickley et al. (1984) | Optimal control of a single basin tidal system | Dynamic programming | It maximize the energy production of the system |

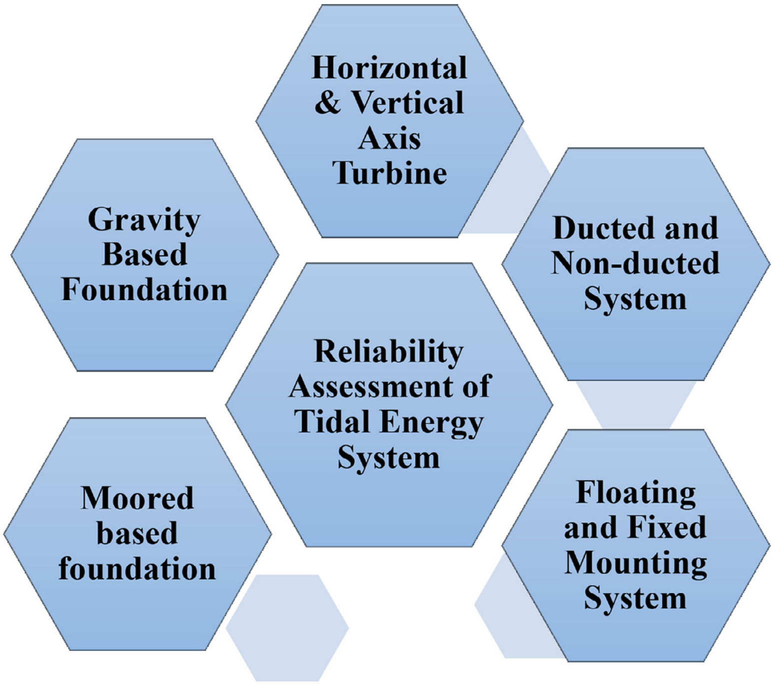

**Fig. 5.** Reliability assessment of tidal energy system.

reliability analysis of tidal energy systems. Walkar et al. (2020) describe tidal turbine deployment reliability assessment. Between 2003 and August 2020, 58 tidal stream energy deployments were examined in this article. The research examines commonality, success, and engineering issues to educate current and future initiatives. The most prevalent cause of failure was blade failure, followed by generator and monitoring failures. Ducted devices and devices in high-velocity settings had a higher failure rate, suggesting that flow velocity had a major influence. Fig. 5 shows the different components of the reliability assessment of tidal energy systems.

Dimitri et al. (2014) describe the examination of the rotor blades of tidal turbines for dependability. The paper demonstrates how this may be done to design rotor blades of longitudinal marine current propellers in the context of bending failure due to excessive stress. The basic characteristics of such turbines, particularly their blades, are briefly discussed first. The authors present a probabilistic model of tidal current velocity variations, the primary source of load uncertainty. The blades' dependability research is discussed, considering unknowns such as tidal current pace, blade reluctance, and the method used to determine bending moments in the blades.Khare et al. (2019) describe the reliability analysis of tidal energy systems. This chapter utilizes the breakdown distribution system, time-dependent breakdown model, and consistent rate of failure model to assess the tidal energy system's dependability. The Bayes theorem, Birnbaum's measure, and risk accomplishment worth-based reliability analysis are all discussed in this article. The tidal energy system's risk and failure rate are determined using fault tree analysis. Finnegan et al. (2020) describe how computational fluid dynamics (CFD) is used to analyze operational degradation forces on tidal turbine blades to undertake the investigation. A model of a concept 17 m diameter horizontal axis tidal turbine with a monopole support structure is developed. According to an investigation of operational fatigue loadings induced by differences in the position and diameter of the support structure, tidal turbine blade loads varied by up to 43% of the maximum total thrust force. Liu et al. (2016) describe the reliability assessment of tidal energy systems with battery energy storage. The tidal power generating system (TPGS) is studied using a sequential multiple-state probability framework. The TPGS force outage rate and the unpredictable character of tidal current speed are taken into account in this model. A TPGS contains a power electronic converter in which electronic component failure rates penetrate their junction at high temperatures. In contrast, a TPGS or WPGS's junction temperatures depend on provided powers. Fig. 6 shows the failure and load cases of tidal power plants, which shows the chances of failure due to the floater out of water during the storm and the failure of different components. Table 4 shows the yearly failure rates for tidal turbine subsystems across the world.

Liu et al. (2015) describe a reliability study of tidal power plants with the tidal speed consideration. This work presents a technique for evaluating the dependability of a tidal power generation system (TPGS) employing a doubly-fed induction generator. The proposed method's primary features are modeling rotor side converter (RSC) and grid side

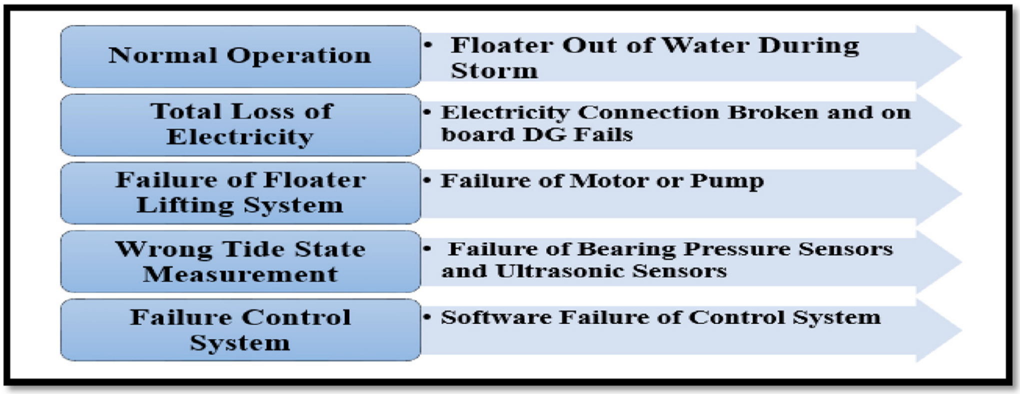

**Fig. 6.** Failure and load cases of tidal power plant.

**Table 4**
Yearly failure rates for tidal turbine subsystems across the world.

| Subsystems | Failure Rate |
|---|---|
| **Rotor** | **0.245** |
| **Pitch Control** | **0.096** |
| **Bearing on the main shaft** | **0.041** |
| **Gear-box** | **0.130** |
| **Generator** | **0.049** |
| **Mechanical Brake** | **0.037** |
| **Electrical Controls** | **0.270** |
| **Hydraulics** | **0.190** |
| **Electrical System** | **0.478** |

converter (GSC) failure rates as a function of tidal current speed. According to the data, the failure rates of the RSC, GSC, and the whole TPGS vary with tidal current speeds and tidal current velocity probability distributions. The TPGS is considerably more likely to fail in super-synchronous mode than in idle or sub-synchronous mode. Fig. 7 shows the Tidal Energy System Reliability Indices.

During the reliability analysis of tidal energy systems, breakdown frequency, average breakdown times, mean time between failures, and energy not delivered to be determined. These indices are used to define the tidal energy system's technical and management aspects. The loss of load probability of the tidal energy system is based on the peak hour load or the number of consumers who take the supply from the tidal power plant. Considering $S_t$ and $L_t$ are the supply and load demand of the tidal power plant, and the reliability index $R_t$ of the tidal energy system is given by

$$R_t = Pr\left(S_t \geq L_t\right) \text{ or } R_t = 1 - Loss\ of\ Load\ Probability\ of\ Tidal\ Energy\ System$$

In the other form reliability index is also given by

$$R_t = \frac{1}{\sum_{i=1}^{n} T_i} \sum_{i=1}^{n} \mathbf{Pr}(St \geq Lt)T_i \tag{7}$$

Where the operation period of tidal power plant T is distributed into 'n' intermissions, and each intermission has a duration $T_i$ and prerequisite energy demand is $Lt$.

The length of time on which tidal energy generating capacity is inadequate is shown by tidal power plants' loss of load probability. For the tidal energy system, where the residual energy production capability is $G_i$, the fraction of time is ti. In that case, energy demand exceeds $G_i$ can be resolute from the load curve L. So the loss of load probability is given by

$$LOLP = \sum_i P\left[G = G_i\right] P\left[L > G_i\right] = \sum_i \frac{p_i t_i}{100} \tag{8}$$

Where $p_i$ is the probability related to the number of failed generating units of the tidal power plant at the time $t_i$.

The electrical utility calculates reliability indexes in every tidal power plant annually. The following reliability index directly or indirectly affects the decision-making criteria of the tidal power plant.

The Expected Frequency of Load Curtailment (Fault/Year) of the tidal power plant is given by

$$EFLC = \sum_{k=1}^{m} \gamma_k \tag{9}$$

The Expected Duration of Load Curtailment (Hours/Year) of the tidal power plant is given by

$$EDLC = \sum_{k=1}^{m} \gamma_k t_k \tag{10}$$

The Expected Energy Not Supplied (kWh/Year) of the tidal power plant is given by

$$\mathbf{EENS = L.(EDLC)} \tag{11}$$

Where$\gamma_k$, $t_k$ is the load curtailed at a considered load, and k and L are the item's failure rate and failure duration.

Mirzadeh et al. (2019) describe the evaluation of reservoir-based tidal power plants' dependability. This study provides a probabilistic framework for incorporating large-scale tidal plants into operating power systems based on the modified PJM technique. A multi-state reliability model is created and used in operation studies in this context, considering both the failure rate of composing components and tidal level change. Essential indices such as unit commitment risk needed spinning reserve, and peak load carrying capacity may be determined for analyzing the impact of a tidal power plant on power system operational studies using numerical examples. Ghaedi et al. (2020) describe the impact of tidal height variations on the reliability of barrage-type tidal power plants. Using analytical and Monte Carlo methodologies, a multi-state reliability model of a barrage-type tidal energy conversion system with a variable failure rate of components is used to study the generating power systems adequacy. This model may also assess the dependability of a composite power system that incorporates tidal power facilities of the barrage type. The variable failure rate of components creates a more realistic dependability model for a tidal power plant. This model can effectively assess the effects of various tidal patterns on dependability indicators. Fig. 8 shows the flow chart of the reliability model of the tidal power plant. It starts from collecting data of different parameters at different intervals and ends with measuring the failure rate and repair rate of the different component of the tidal energy system.

Delorm et al. (2022) describe tidal stream devices and comparison models. The current paper presents such an approach and produces system dependability prototypes for four common-design, horizontal-axis, tidal stream strategies, all rated at 1–2 M.W. Historical reliability data from similarly rated wind turbines and other relevant maritime datasets

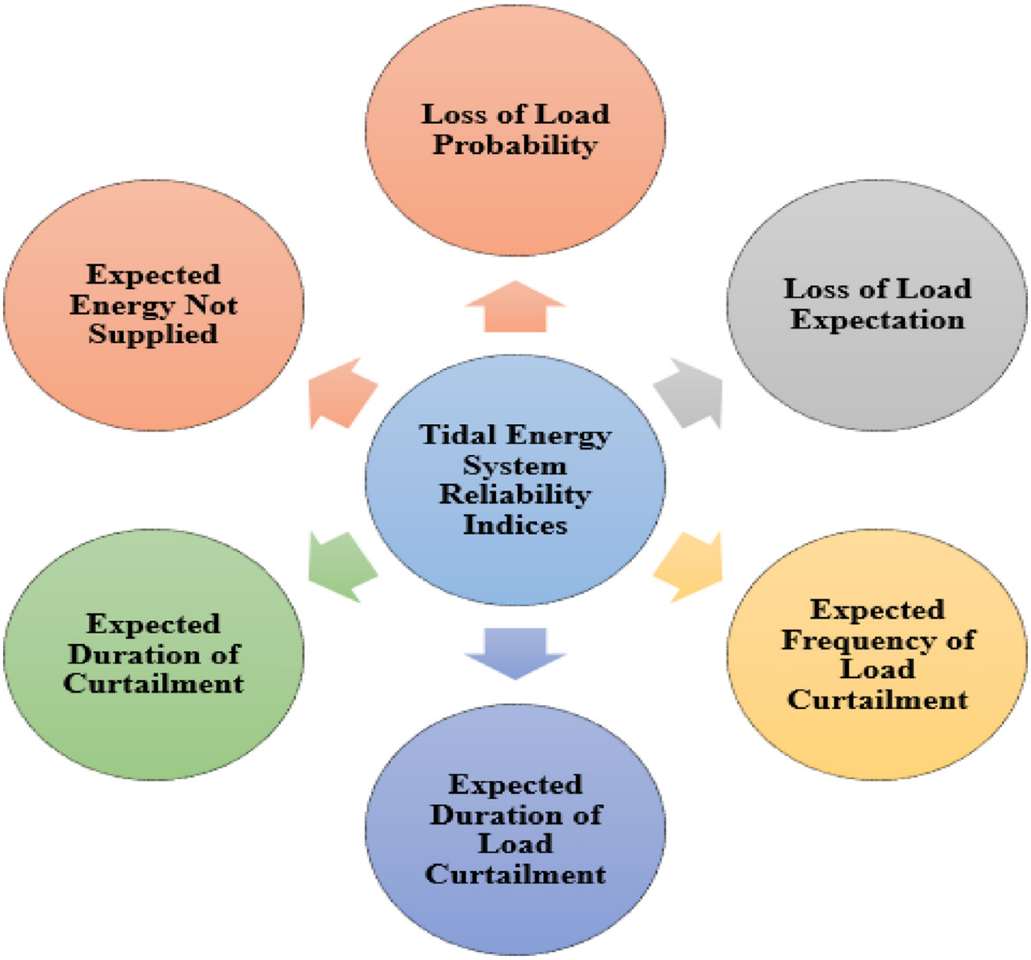

**Fig. 7.** Tidal energy system reliability indices.

were used to feed the generated reliability models. The study discovered that tidal stream devices are less dependable than wind turbines of comparable size and that failure rates increase as the device becomes more sophisticated.

**Outcomes:** According to the above discussion, it is found that in the present scenario, reliability analysis is the essential concern in identifying the fault rate of the overall tidal power plant. Using this model, the effects of varied tidal patterns on the dependability indices may be accurately evaluated. The failure rate and reliability of altered mechanisms of a tidal power plant, including single and three-phase transformer, hydraulic turbine, number of cables, generators, and various converter types, depends on the tidal height and tidal velocity. During the reliability analysis of tidal energy systems, it is necessary to identify failure frequency, average failure times, mean time between breakdown, and energy not delivered. Such indices are used to define tidal energy systems' technical and managerial parameters. A tidal energy system's loss of load probability is based on the peak hour load or the number of consumers who take the supply from the tidal power plant.

## 6. Optimization technique in tidal energy system

One of the essential aspects of a tidal energy scheme is to analyze the most appropriate location and optimum design of different components, which directly or indirectly affect the functioning of a tidal power plant. Other optimization techniques are used to identify the most appropriate parameter or optimum value of all the technical parameters of a tidal power plant. Many researchers are already working on the genetic algorithm, particle swarm optimization, big bang big crunch, cuckoo optimization, and multi-objective modified bird mating optimizer. Xue et al. (2021) describe the design attributes of tidal energy systems through the genetic algorithm. The scheme's design was also explored using a typical network search method for various situations and the model that is being used to analyze the whole scheme's design performance, as assessed by a comparison of the most optimal selection in terms of power generation. This comparison revealed that the Genetic Algorithm model could generate almost identical results while saving computational time by about 95% compared to standard Grid Search approaches. In most cases, a genetic algorithm is used to identify the sluicing area to create many scenarios for the same scheme with varying installed capacities. The sluice area is given by

$$\begin{aligned} Sluice\ Area = {} & Number\ of\ Turbines \times Installed\ Capacity\ of\ Each\ Turbine \\ & \times Sluice\ to\ Power\ Function \end{aligned} \tag{12}$$

Javidsharifi et al. (2018) explained tidal energy system-based microgrid scheduling through the multi-objective optimization technique. An intellectual evolutionary multi-impartial adapted bird mating optimizer algorithm has been devised. In addition, the problem considers a full financial model of storage components. The results reveal that the proposed algorithm effectively achieves economic and environmental goals. On a practical M.G., the efficiency of the suggested technique is validated by comparing it to the original BMO and PSO. Tahani et al. (2015) analyze the design prospectus of horizontal axis tidal turbines based on the meta-heuristic algorithm. Although the Pareto facades obtained by MOFPA and NSGA-II are of higher quality than those obtained by MOCS and MOPSO, a detailed comparison of the first fronts of MOFPA and NSGA-II revealed that the MOFPA algo-

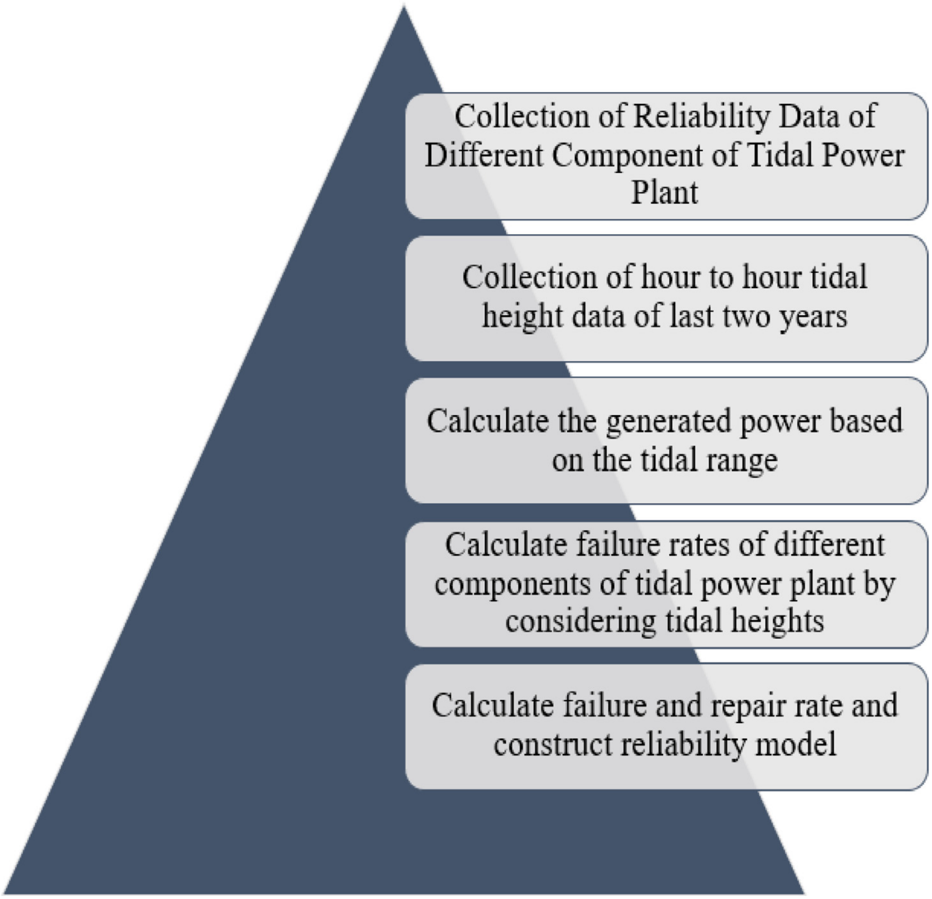

**Fig. 8.** Flow chart of reliability model for tidal power plant.

rithm could obtain the best Pareto front and could maximize the power coefficient by up to 4.3 percent and the produced torque on the stationary blade by up to 57.9%. The first and final members of MOFPA's Pareto front are compared in terms of geometry. Hyperbolic and constant chord distributions characterize the members that create the highest power coefficient, and maximum produced torque on stationary blades, respectively. Through the multi-objective optimization technique, Huang et al. (2015) studied the distribution of front blade pitch angles in horizontal axis tidal turbines. The front blade pitch angle distribution was chosen as an optimization variable in this study because it substantially influences the inlet conditions of the rear blade. According to the numerical data, both the power coefficient and thrust coefficient optimization targets might be considerably improved. It was proven that the power unit's performance with the enhanced blades increases substantially by adjusting the pitch angle. Nandagopal et al. (2020) describe the concept of hydrofoil geometry of tidal turbines through the multi-objective optimization technique. This approach optimizes a basic hydrofoil shape to build a new hydrofoil with improved qualities for the flow circumstances, rather than choosing hydrofoils for a specific flow situation. Hydrofoils were created with the flow conditions in Southeast Asia in mind. The optimization procedure was repeated until the intended goals were met while staying within a set of constraints. The non-conflicting goals were to increase the hydrofoil's lift-to-drag ratio and lift coefficient, while one of the constraints was to minimize cavitation during turbine operation. Faridnia et al. (2019) elaborated on the optimal scheduling of tidal power plants through the optimization technique. This research looks into an M.G. scenario incorporating a small-scale tidal farm near Darwin, Australia's northernmost city. Using tidal current speed data, a tidal power prediction model is presented. Then, using Particle Swarm Optimization (PSO), an efficient scheduling approach for a fixed-size energy storage system (ESS) is created to achieve minimum operating costs in the M.G. The research provided in this study lays forth a framework for M.G.s that want to incorporate tidal power into their energy mix. Fig. 9 shows different Objective Functions with the Optimization Technique of the tidal energy system, which incorporate parametrization. It shows in the objective function, there are number of variable, in the terms of different branches of tree. Genetic algorithm, particle swarm optimization, big bang big crunch, neural network and fuzzy logic are used to identify the optimal value of different parameters such as tidal current, tidal range, economic value, efficiency, load frequency control, sluice area with the help of minimization and maximization function etc.

Han et al. (2021) explained The notion of using a gradient-based optimization approach to find the best design for tidal current turbines in shallow water. This research investigates the macroscopic characteristics of tidal farm layouts optimized for optimal power generation in an assumed shallow channel with continuous unidirectional flow. By changing the number of turbines and optimization constraints, numerical experiments were done using Open Tidal Farm, an open-source solution for tidal farm optimization that uses PDE-constraint gradient-based optimization. Mohanty et al. (2019) describe the overall stability of the TWECS is brought to a stable and normal stage as a consequence of reactive power management and the inclusion of unique power-based devices. In the case of DDPMSG, optimization tools such as PSO, GSA, and PSOGSA are provided for even greater system performance and the effects of the permanent magnet on overall system stability. Zaheeruddin et al. (2020) explain load frequency modification using a fractional fuzzy-based PID droop controller for de-loaded tidal turbine power plant units. Using a fractional-order (F.O.) fuzzy PID droop in a de-loaded section improves the frequency excursion of fixed/fuzzy PID/PID droop controllers. The Imperialist Competitive Algorithm (ICA) is employed to fine-tune the controllers' settings. The ICA

**Fig. 9.** Objective function with optimization technique.

optimized fractional order PID droop control approach outperforms the integer-order fuzzy PID control and PID droops control, with a settling time of 11.65 s, an undershoot amplitude of 0.26pu, and a performance index of 0.0. Hibbert et al. (2015) describe recent real-time tide gauge data, an empirical technique to enhance the developed tidal forecasts. The most effective method was the Empirical Correction Method, a simple methodology for correcting Harmonic Method H.W. predictions using current data. It was successfully applied to sea-level records from 42 of the 44 U.K. Tide Gauge Network stations. It will be incorporated into the operational systems of the U.K. Coastal Monitoring and Forecasting Partnership to enhance short-term sea-level predictions in the U.K. Sahu et al. (2021) describe tilt fuzzy cascade controllers with DQN optimization for occurrence constancy in a tidal energy-based A.C. microgrid. Gunn et al. (1992) developed optimization structures for tidal energy systems. This research presents an optimization methodology for screening alternative tidal power plant designs at the preliminary design stage. We begin by discussing tidal power optimization to set the stage for the rest of the paper. Then, an overarching system model is offered for its solution, coupled with a decomposition approach. The solution of the sub-models corresponding to the tidal, hydroelectric, pumped storage, and thermal subsystems aid the breakdown. Zhang et al. (2018) describe the grey GMDH neural network used to create a real-time prediction model. The final prediction result is obtained by combining the estimation outputs of the harmony analysis model and the Grey-GMDH model. The testing database is made up of measured tide-level data from the San Diego tidal station. According to simulation and experimental data, the suggested approach may accomplish real-time tidal level forecasts with high accuracy, excellent convergence, and stability.

**Outcomes:** The goal of optimization, it turns out, is to come up with the "optimal" design based on a set of prioritized criteria or constraints for the tidal energy system. These functions include optimizing productivity, strength, dependability, lifespan, efficiency, and the use of many technological, economic, and environmental aspects. Table 5 shows the summary of the above discussion. In the recent scenario, lots of optimization technique such as cuckoo optimization, big bang big crunch, and particle swarm optimization is also used to identify the optimum value of cost function and efficiency of the tidal energy system.

**Table 5**
Summary of application of optimization technique in tidal energy system.

| Author | Study Area | Objective | Optimization Technique | Outcomes |
|---|---|---|---|---|
| Xue et. al. (2021) | Bristol Channel U.K. | Schemes for generating electricity from the tidal range | Genetic Algorithm | Optimize the range of tidal range scheme<br>Optimize no. of turbines and sluice gate areas<br>Optimize the design of tidal lagoon |
| Javidsharifi et. al.(2018) | Lake Saroma Hokkaido Japan | A renewable-based microgrid's multi-objective short-term management | Multi-objective modified bird mating optimizer | Economic and Environmental Analysis<br>Optimize micro grid dependency on the main grid<br>Satisfy the power balance equality constraints |
| Tahani et. al. (2015) | - | Tidal current turbines with horizontal axis multi-objective computation | Meta Heuristic Optimization Algorithm<br>Particle Swarm Optimization<br>Cuckoo Optimization | Power coefficient and Produced Torque on Stationary Blade |
| Huang et al. (2015) | - | The front blade pitch angle distribution was optimized numerically using a multi-objective approach. | Genetic Algorithm | Power Coefficient and Thrust Coefficient Improved.<br>The Pitch angle of the front blade in the counter-rotating type tidal turbine was optimized |
| Nandagopal et. al. (2020) | Tropical conditions of South East Asia | Multi-objective evaluation of hydrofoil shape for tidal turbines with the horizontal axis | Open MDAO NSGA-II | Optimize lift-to-drag ratio and lift coefficient |
| Faridnia et. al. (2019) | Darwin North of Australia | Effective tidal production management in a microgrid | Particle Swarm Optimization | Tidal current observation and optimization fixed size energy storage system |
| Han et. al. (2021) | - | A tidal current turbine farm's optimal setup | | Cost minimization and maximizing power product |

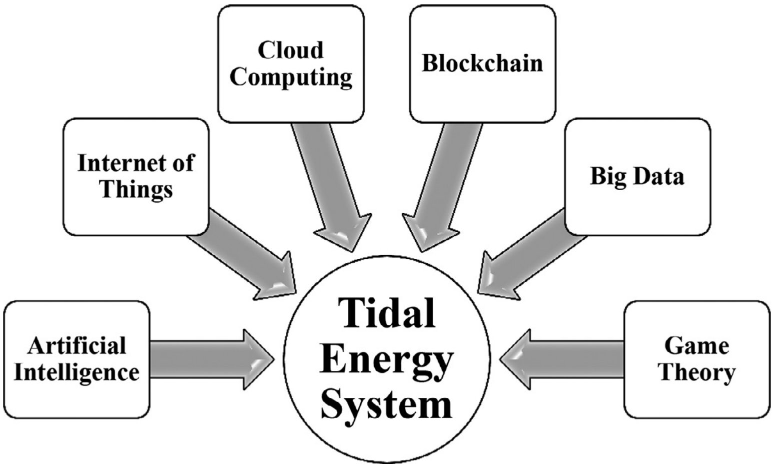

**Fig. 10.** Recent technology in the field of the tidal energy system.

## 7. Recent trends and future perspective in tidal energy system

According to the above discussion, lots of work is ready to be done in tidal energy systems. Now it is necessary to apply the recent technology to assess tidal energy systems to create sustainable environment. In the present scenario, artificial intelligence, the internet of things, block-chain, cloud computing, and game theory are going forward and adopted by the different renewable energy power plants to enhance performance and create an efficient energy management system. These techniques work with integrating advanced information and communication systems that have led to a transformation of traditional systems into a smart working environment and to create sustainable energy to the environment. Fig. 10 shows recent technology in the field of tidal energy systems, and which is also play significant contribution to create sustainable environment.

Sreeni et al. (2017) analyzed machine erudition-based extreme point tracking of tidal energy conversion systems. Sea temperature, tidal height, tidal range, and tidal turbine hub height are the input parameters in the machine learning test and training data set. It is found that machine learning-based hill climb search has considerably faster conjunction to the maximum power point than regular Hill Climb Search. Zhong et al. (2018) developed an artificial neural network-based real-time tidal prediction model. The final prediction result was obtained by merging the estimation outputs of the harmony analysis model and the Grey-GMDH model. The testing database is made up of measured tide-level data from the San Diego tidal station. According to simulation and experimental data, the suggested approach may accomplish real-time tidal level forecasts with high accuracy, excellent convergence, and stability. Janssen et al. (2015) analyzed potential sites for tidal energy systems through different decision support tools. Local knowledge is combined with regional attributes in a value mapping tool. These value maps are being used as part of a negotiating assistance tool to help stakeholders find suitable sites for tidal energy devices. Interactive value mapping was proven to be useful in filling in data gaps and increasing map trust. The negotiating tool-assisted parties in balancing the goals of numerous stakeholders. Fig. 11 shows the Application of Recent Trends in the Tidal Energy System. Table 6 shows the different purposes of a tidal energy system with artificial intelligence.

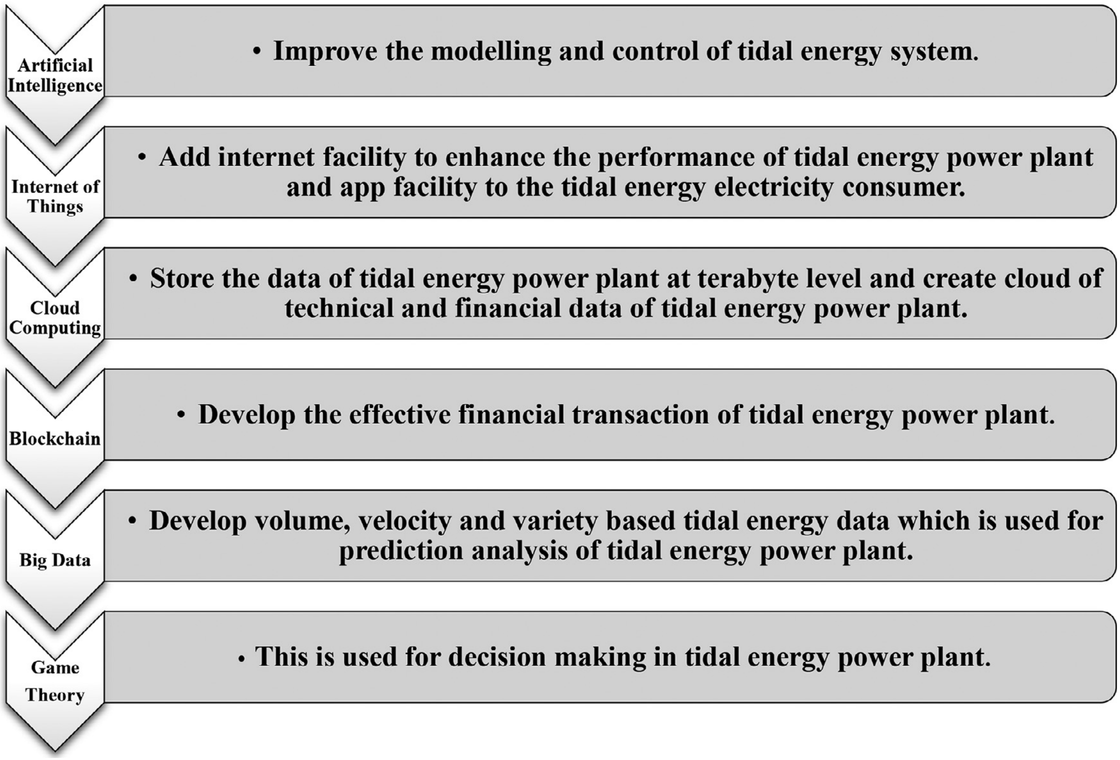

**Fig. 11.** Application of recent trends in tidal energy system.

**Table 6**
Future aspects of tidal energy system with application of artificial intelligence.

| |
|---|
| Tidal energy system optimization |
| Bulk energy consumption control and management |
| Load frequency control |
| Energy modeling of a Tidal Turbine |
| Targeted energy storage solution |
| Estimation of Tidal Current |
| Estimation of Tidal Height |
| Thermodynamic analysis of Tidal Turbine |
| Tidal power forecast |
| Forecasting and optimization of tidal model |
| Modeling of a Barrage system |
| Tidal farm decision system |
| Tidal farm density forecasting model |
| Prediction of full-scale thrust for floating wind turbine |
| Short term tides speed forecasting |
| Maximum power point tracking in tidal energy |
| Optimization for cleaner production of tidal energy |
| Prediction model of technical properties of tidal energy |

According to the future perspectives, artificial intelligence is the key technology to enhancing the performance of tidal energy systems. Lots of work has already been done in the field of tidal energy systems with the concept of artificial intelligence; further followings are some possibilities and future scope of this technology in the area of tidal energy systems.

- Develop a drone-based system for finding a suitable location where sufficient amounts of tidal current and tidal height exist for the tidal power plant.
- Develop a robotic automation system for maintenance of tidal power plant.
- Develop a machine learning-based reliability measurement system for the tidal energy system.
- Develop an artificial intelligence-based control mechanism for the tidal energy system. The height of tide and wave height is the input parameter for supervised and unsupervised learning for artificial intelligence systems.

It's at the heart of a burgeoning ecosystem of big data technologies, which are largely used to support advanced analytics projects like predictive analytics, data mining, and machine learning. Following is the possibility through big data analysis in tidal energy systems.

- Create a Hadoop Distributed File System (HDFS) for tidal energy power plant data, which is also used for predictive analysis of tidal power plants.
- Create a basket model of reliability analysis of tidal power plant.

A blockchain is a decentralized public record of data collected via a network that sits on top of the internet. Block chain's revolutionary potential is based on how this information is recorded. A number of future scope of blockchain are possible in tidal energy systems.

- Create a financial system for the tidal power plants through blockchain technology.
- Create a system in which the process of electricity bill of the consumer is to be done through blockchain technology.

## 8. Conclusion

According to the above discussion, lots of work is already to be done in tidal energy systems. Now it is necessary to apply the recent technology to assess tidal energy systems. The objective of this paper, is to introduce significance of different aspects of tidal energy system, because this technique most rarely used for the power generation. So it is necessary to identify the suitable location, which generate electricity from the tidal energy system. It is also essential to identify more suitable methods for proper unit sizing of tidal energy components and the most appropriate control system to enhance the performance of the tidal energy system. Research also shows that to reduce greenhouse gas emissions soon, it is necessary to identify a more suitable location for electricity generation through the tidal energy system. The main challenges face in tidal energy system, to identify proper resource allocation with the perfect basin size.

In the future perspective, artificial intelligence, the internet of things, block chain, cloud computing, and game theory are going forward and adopted by the different renewable energy power plants to enhance performance and create an efficient energy management system. These techniques work with integrating advanced information and communication systems that have led to a transformation of traditional systems into a smart working environment. So at the end, it is necessary to adopt such type of techniques to enhance the performance of the tidal energy system.

## Conflict of Interest

None.

## Data availability

Data will be made available on request.

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