Providing marginal areas of the Northern Sea Route with radio communications when using dam-free hydropower plants

L F Borisova and A N Korobko
Murmansk State Technical University, Murmansk, Russia
lfborisova@mail.ru

Abstract. According to the Navigation Rules in the Northern Sea Route (NSR), the skipper should receive all types of information support for safe navigation in the Arctic zone, including navigation, hydrometeorological and hydrological. In order to maintain safe and efficient navigation, the NSR routes should receive navigation safety information from the transmitting points of the NAVTEX system. For this, along the NSR route, it is necessary to have a developed network of coastal and base transceiver stations. Effective information and technological support of the NSR route is prerequisite not only for the safe conduct of ship traffic, but also for the successful civilizational development of the coast, including the deployment and maintenance of the tourism industry. The inaccessibility, territorial distance from the main centers of management and the harsh climate make the NSR areas unprofitable for development in the foreseeable future. Under these conditions, only radio communication, which is not critical to the features of the soil cover and does not require expensive cabling of communication facilities, is an economical means of information and communication support for such territories. The most problematic of NSR radio technical support is the extremely low level of energy supply to the North and the Far East. Possessing the longest sea coastal zone, and occupying one of the leading places in the world in hydropower resources, Russia uses its hydropower potential by only 20%. The situation is aggravated for inaccessible territories for which problems in the field of energy cannot be solved by traditional methods. It is economically unprofitable or simply impossible to use large hydroelectric power stations to power hard-to-reach facilities on the NSR routes. The solution may be the use of small hydropower. To solve the problem of fast, low-cost and efficient energy supply of marginal and inaccessible territories, a new constructive solution for mini-hydropower plants has been proposed. The developed design of mini-hydroelectric power plants does not require the construction of dams, or artificial reservoirs, which allows to increase efficiency compared to the traditional approach.

1. Materials and methods
Russia's plans to increase its presence in the Arctic zone, the socio-economic development of the Arctic coast and the development of the Northern Sea Route (NSR) cannot be implemented without the creation of modern information and telecommunication infrastructure that ensures the functioning and interaction of all business entities.

The rules of navigation in the waters of the Northern Sea Route determine the receiving by the skipper all types of information support for safe navigation in the Arctic zone, including navigation,
hydrometeorological and hydrological information [1]. An ice pilot uses a ship’s radio station and other means of communication to guide a ship [2].

The safety and efficiency of navigation along the NSR routes should be supported by information received from the transmitting points of the NAVTEX system and an extensive network of coastal and base transceiver stations. They provide HF communications between ships and coastal services, monitoring of ships, transmission of distress messages to marine rescue coordination centers (MSCC) and sub-centers (MSCC), as well as the implementation of other production tasks at the proper quality level.

Effective information and technological support of the NSR route is a prerequisite not only for the safe conduct of ship traffic, but also for the successful gradual civilizational development of the coast, including the deployment and maintenance of the tourism industry.

The inaccessibility, territorial distance from main centers of management and harsh climate make the NSR areas unprofitable for development in the foreseeable future. Under these conditions, only radio communication, which is not critical to the features of the soil cover and does not require expensive cabling of communication facilities, is an economical means of providing information and communication support for territories, providing navigation, hydrometeorological and other services.

Placing on the coast along the NSR route the coastal and base radio stations and radio communication centers as well as energy supply can contribute to the successful development of hard-to-reach lands of the Arctic zone and the Far East.

The most problematic area hindering the solution of radio technical support of the NSR is the extremely low level of energy supply to the North and the Far East. Having the longest sea coastal zone, and occupying one of the leading places in the world in terms of providing hydropower resources, Russia uses its hydropower potential by only 20%. The situation is aggravated for inaccessible territories for which problems in the field of energy cannot be solved by traditional methods. These include plans for the development of the Northern Sea Route.

The experience in the construction and operation of hydraulic power plants (HPS) made it possible to summarize the advantages and identify their main disadvantages. To power hard-to-reach facilities (including the NSR route), large hydropower plants are economically unprofitable or impossible to use. An alternative is small hydropower.

In this work, the authors have proposed a new constructive solution for mini-hydropower power plants that can efficiently, not expensive, and quickly solve the problem of energy supply for marginal and inaccessible territories, including the location of coastal and base radio stations and radio communication centers.

The proposed design of mini-hydropower power plants does not require the construction of dams, artificial reservoirs or the use of reservoirs, which allows to increase efficiency compared to the traditional approach.

2. Research methods and objects

Three types of hydraulic power plants are most known [3]: hydroelectric power stations (HPS), tidal hydroelectric power stations (THPS) and pumped storage power plants (PSPP).

The technology for generating electric energy at a modern hydroelectric power station requires the creation of a dam and a reservoir (upper downstream), a turbine water conduit with a hydrogenerator to generate electricity and a lower downstream for the discharge of waste water. The amount of power generated by the hydrogenerator directly depends on the height of the difference between the upper and lower pools. The cost of generated electricity is low, but the construction costs are quite high.

The principle of operation of the tidal station is based on the use of tidal wave pressure. The main disadvantages of PES are the dependence of electricity generation on the characteristics of the tides and the high cost of structures.

The operation of the pumped storage power plant is based on pumping between the upper and lower basins.
In general, hydropower plants are quite efficient sources of energy, as they use renewable resources, are easy to manage, have high efficiency and low cost of electricity production. In addition, automatic start and shutdown occur quite quickly, and the number of units is unlimited.

The disadvantages of hydroelectric power plants are long construction time with high specific investment, possible flooding of large land areas, continuity of the technological process, which cannot be stopped, the environmental damage caused by pool pollution and damage to fisheries during the spawning period.

The proposed small damless coastal hydroelectric power station eliminates most of these shortcomings. The prototype of the development was the “siphon unit with upward water drainage” of physicists J. Arnoux and J. Klyasuan [4]. This is a vertical unit with a generator located under the turbine. Here, water is supplied from below to the impeller and is sucked off using a siphon placed above the impeller. Advantages include increased efficiency, absence of a machine building, profitability in building materials, ease of installation, a sufficiently high efficiency (70-74%) with not too high loads.

However, the normal operation of the siphon is possible provided that the vaporization pressure must exceed the minimum absolute pressure in the siphon pipe. With an increase in head height, air begins releasing from the water. In addition, the weight of the unit is slightly more than usual due to the extended diffuser.

The principle of operating the proposed design of a damless hydroelectric power station, like ocean thermal power plants (OTPP), uses the energy of the temperature gradient of sea water occurring due to temperature differences in different surface layers of the oceans [5]. Regardless of the type of station (open, closed or hybrid), energy is obtained by heat transfer. The greater the difference in water temperature, the higher the efficiency.

The basic structural element is a pipe with a large diameter, having a length of several hundred meters. One end of the pipe is immersed to the depth of the cold layers, water is taken from there and raised to the surface with its help. An upward flow of water cools the part of the system within which the working fluid circulates – water or a low boiling component (freon, propane, ammonia). In the heated part of the system, the working fluid evaporates forming gas under pressure, which rotates the turbines of the generator producing electricity. In the cooled part of the system, the gas condenses, and the cycle of transformations is repeated [6].

In addition to electricity production, OTPP also have other advantages: wide selection of areas for accommodation; possibility of desalination of water; raising bioactive components and nutrients from the depths; economical hydrogen production through electrolysis; economical hydrogen production through electrolysis; ability to generate energy in the dark, in cloudy and calm weather and some others. However, the efficiency of OTPP stations does not exceed 8% because of large energy losses due to the low efficiency of the structure. Energy-intensive is the rise of cold water; some specialized underwater equipment made from expensive composite, as well as synthetic materials and scarce metals are required for station operation. There are some other problems [7].

Nevertheless, the central reason for the low efficiency in our opinion is a design flaw embedded in the world’s first hydrothermal station (1927–1930) by its developer Georges Claude [8]. In the design, the heat engine is located on the surface of the ocean, and cold water is pumped to the surface through a pipe using a pump that consumes a significant amount of energy.

The proposed constructive solution is based on the property of a homogeneous liquid (working fluid) to occupy a position of stable equilibrium, being placed in communicating vessels. It is known that with a decrease in height (h1<h2) in any branch of communicating vessels, the equality of pressures (P1=P2) at the lower points of these vessels is violated. This causes a homogeneous fluid to move until a stable equilibrium is established, at which the relations h1 = h2 and P1 = P2 are observed.

The developed design of a small damless submersible hydroelectric power station differs from the traditional technological solution. Water here is not pumped into the pipe with the pump from the bottom up to raise it to a heat engine placed on the surface. The water rises from the depth itself under the pressure of ocean water according to the principle of communicating vessels and is pumped upward through the axial pump located on the surface. A water turbine with a generator is installed at a depth
(approximately 700 meters) of the reservoir at the base of the water conduit with holes for water to flow into the pipe. The flow of water up the pipe to the position of stable equilibrium and its return to the reservoir create hydraulic pressure on the turbine. A synchronous generator produces electricity of industrial frequency and voltage. The developed technological solution is protected by a patent [9]. The principle of operation of the damless submersible mini-hydroelectric power station is illustrated in Figure 1.

![Figure 1. Principle of operation and construction of a damless power station:](image)

1 – working fluid (water); 2 – conduit; 3 – mounting pad; 4 – holes for water inflow; 5 – a protective grid; 6 – hydroturbine; 7 – electric generator; 8 – platform; 9 – axial pump

The water conduit (2) in its lower part abuts against a platform (3) fixed at the bottom of the reservoir, and has openings (4) for water inflow (1), which are protected by a grid (5). Above the inlets is a hydraulic turbine (6) connected to an electric generator (7). The water pipe is connected with the upper part to the platform (8), which is fixed on the shore. The upper part of the water conduit is placed above the reservoir level and has a bend towards the reservoir. An axial pump (9) is installed on the bend of the pipe (for example, with a variable adjustable pitch screw and an efficiency of 0.8-0.86, a lifting height of 6-8 meters [10]) with an adjustable pitch screw whose blades are immersed to a depth of 1-2 meters. The water is pumped out of the pipe by the pump and returned to the reservoir. The pump performance should not be lower than the water flow in the turbine, and the power consumption for raising and removing water (to a height of 1-3 meters) from the pipe is much less than the power that the hydrogenerator produces. The expected capacity of a mini-hydroelectric power station is determined by the depth at which the turbine is installed.

The proposed technical solution removes the restriction on the placement of mini-hydroelectric power stations. The designed power station can be placed on the shore or on the roof of a high-rise building providing air conditioning in the hot season. It has several advantages including:
- absence of need for constructing a dam, or an artificial reservoir;
- does not require large investments;
- a wide selection of places for use: the shore of the ocean, sea, lake, drifting ice floe, island, rock, tower, building and others;
- unlimited increase in power of the power system by connecting additional modules;
- there is no need for fossil fuels, nuclear, solar, wind and other types of energy;
- use of a natural renewable resource.

3. Conclusion
The efforts of many countries in recent years have been aimed at finding commercially promising ways to extract and use the energy of the seas and oceans. In Russia, alternative hydropower remains
largely experimental due to the abundance of traditional energy resources. However, alternative sources are already seriously considered as a prospect of electricity supply to the Crimea.

Another promising area for the application of these types of energy resources is the development of the Northern Sea Route, associated with the growth of navigation and the development of the tourism industry. Hard-to-reach and unprofitable coastal areas along the Northern Sea Route are in dire need of affordable and economical sources of energy located locally and operating autonomously, which can power information and communication facilities to ensure the safety of navigation and tourism facilities in the Arctic zone.

The invention was awarded the Silver Medal at the XVIII Moscow International Inventions and Innovative Technology Salon "ARCHIMEDES" (Moscow, 2015) and the Gold Medal at the XIV International Salon of Inventions and New Technologies "NEW TIME" (Sevastopol, 2018).

References
[1] Order of the Ministry of Transport of the Russian Federation of January 17 2013 N 7 Rules for navigation in the waters of the Northern Sea Route
[2] Order of the Ministry of Transport of the Russian Federation, Ministry of Communications and Informatization of the Russian Federation State Committee for Fisheries of the Russian Federation of November 4 2000 N 137/190/291 Radio Regulations of the Maritime Mobile Service and the Maritime Mobile Satellite Service of the Russian Federation
[3] Sibikin Yu 2012 Alternative and Renewable Energy Sources (Moscow)
[4] Shchapov N 1961 Hydroelectric Turbine Equipment (Moscow, Leningrad)
[5] Energy generation from the temperature gradient of water Available from: https://cosmos.mirtesen.ru/ [Accessed 20 November 2019]
[6] Gradient-temperature Energy (OTPP systems) Available from: http://nek-npo.ru/ [Accessed 20 November 2019]
[7] Problems and Prospects of Hydrothermal Energy Available from: https://cosmos.mirtesen.ru/ [Accessed 20 November 2019]
[8] Transformation of Thermal Energy of the Ocean. The Idea of D'ARCONVAL and the Work of Claude Available from: http://vuzllib.su/ [Accessed 20 November 2019]
[9] Korobko A N 2014 Damless submersible modular universal coastal hydroelectric power station and energy complex, consisting of several modular hydroelectric power plants, united by a common platform RU Patent 2520336
[10] Cherepanov B E 1986 Ship Auxiliary and Fishing Mechanisms, Systems and Their Operation (Moscow)