Tidal Energy and Main Resources In the Persian Gulf

Mofid Gorji-Bandpy
Mohammadreza Azimi
M. Jouya

ABSTRACT

Due to increasing concern over global climate change, many policy makers worldwide have accepted the importance of reducing greenhouse gas emissions, in particular from the electricity industry. Tidal generation has a significant advantage over many other forms of renewable generation as it is almost perfectly forecastable over long time horizons. Thus, incorporating tidal generation into an electricity system should be less challenging than other forms of renewable generation which are relatively unpredictable. In this article, we discussed about the capacity benefit of tidal generation, especially in Iran.

Keywords: Renewable Energy, Tidal Energy, Current Energy, Iran, Persian Gulf.

INTRODUCTION

Tidal energy is the energy dissipated by tidal movements, which derives directly from the gravitational and centrifugal forces between the earth, moon and sun. The gravitational force of the moon, due to it being closer to the earth, is 2.2 times larger than the gravitational force of the sun [1]. These forces cause the rhythmic rising and lowering of ocean waters around the world that result in Tide Waves. The moon exerts more than twice as great a force on the tides as the sun due to its much closer position to the earth. As a result, the tide closely follows the moon during its rotation around the earth, creating diurnal tide and ebb cycles at any particular ocean surface. The amplitude or height of the tide wave is very small in the open ocean where it measures several centimeters in the center of the wave distributed over hundreds of kilometers [2].

Tidal energy has been exploited on a significant scale since the construction of the La Rance tidal barrage in France in 1967. A tidal barrage utilizes the potential energy of the tide and has proven to be very successful, despite opposition from environmental groups. Kinetic energy can also be harnessed from tidal currents to generate electricity and involves the use of a tidal current turbine. This is the more desired method of capturing the energy in the tides [3].

The rise and fall of the sea level can power electric-generating equipment. The gearing of the equipment is tremendous to turn the very slow motion of the tide into enough displacement to produce energy. Tidal barrages, built across suitable estuaries, are designed to extract energy from the rise and fall of the tides, using turbines located in water passages in the barrages. The potential energy, due to the difference in water levels across the barrages, is converted into kinetic energy in the form of fast moving water passing through the turbines. This, in turn, is converted into rotational kinetic energy by the blades of the turbine, the spinning turbine then driving a generator to produce electricity. Comparing with wind power energy and solar energy, tidal power seems not a big sustainable resource, but it is doing a fast-rate progress in recent decades. Nowadays and in the coming years, increased attention is being given to the tidal current energy development all over the world. Because of the climate protection, the shortage of oil in future and the increasing demand for electricity the use of renewable energy source for electricity generation is of great importance. The classical hydro power is with approximately 20 % of the worldwide electricity generation the most important renewable source [4]. In the search of other sources recently tidal currents obtained an increased importance. This technology seems to be ecologically suitable as well as economically feasible. The aim of this article is to present the distribution of tidal current energy and the future potential of tidal energy in Persian Gulf.

TIDAL ENERGY

The tidal phenomenon occurs twice every 24 h, 50 min, and 28 s [5]. A bulge of water is created by the gravitational pull of the moon, which is greater on the side of the earth nearest the moon. In parallel the rotation of the earth–moon system, producing a centrifugal force, causes another water bulge on the side of the earth furthest away from the moon illustrated in Figure 1.

When a landmass lines up with this earth–moon system, the water around the landmass is at high tide. In contrast, when the landmass is at 90° to the earth–moon system, the water around it is at low tide. Therefore, each landmass is exposed to two high tides and two low tides during each period of rotation of the earth [6]. Since the moon rotates around the earth, the timing of these tides at any point on the earth will vary, occurring approximately 50 min later each day [7], [8]. The moon orbits the earth every 29.5 days, known as the lunar cycle [7] (Figure 2).

Factors such as the predictability of tidal currents, the relatively large resource estimated in coastal waters, and the advanced development of similar turbine and component technologies have contributed to the significant growth in the development of tidal current concepts over the past decades. Tidal energy is vastly distributed all over the world, such as Rance River in France.

According to the U.S. Department of Energy, traditional (barrage) tidal power requires a difference between high tide and low tide of at

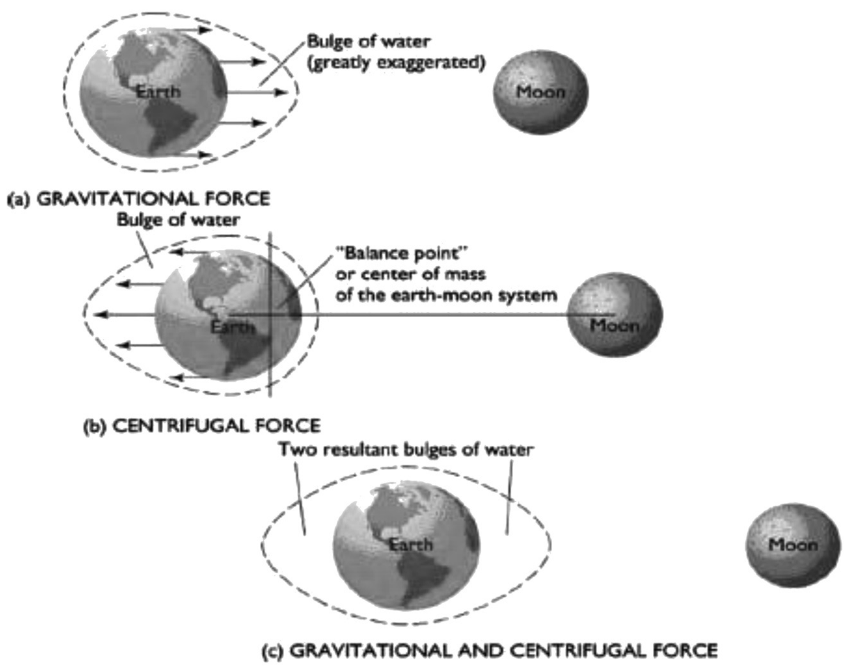

Figure 1. The effect of the moon on tidal range [9].

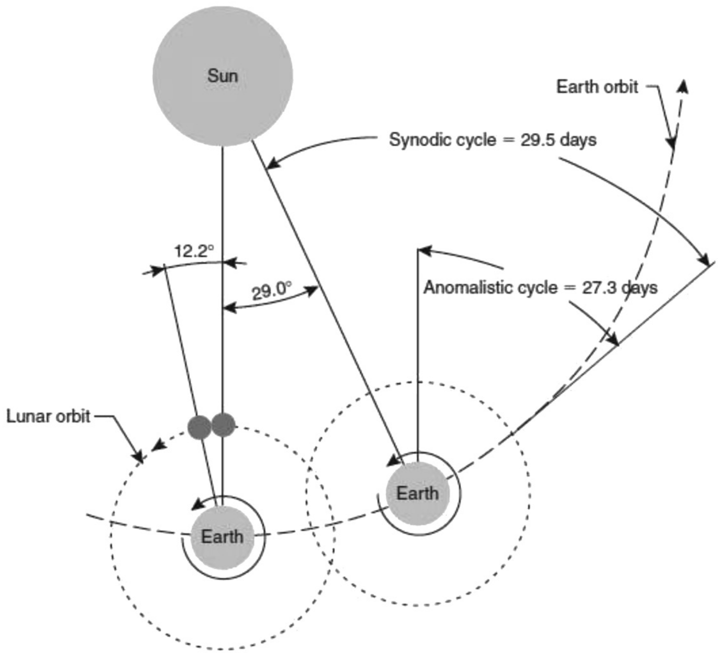

Figure 2. Lunar cycle.[9]

least 16 feet. There are only about 40 such sites worldwide (Figure 3). Tidal stream, on the other hand, simply needs a strong current and, in the case of a tidal fence, a narrow inlet to span.

The first large-scale tidal power plant in the world was built in 1966 at La Rance in France. It generates 240MW using 24 low-head Kaplan turbines. A number of small tidal power plants have also been built more recently in order to gain operational experience and to investigate the long-term ecological and environmental effects of particular locations. The Rance Tidal Power Station in France is the world's first and largest tidal power plant with the capacity of 240MW and the annual output of 600GWh and it has been operating since 1966. North America's only tidal power plant, the Annapolis Royal Generating Station with the capacity of 20MW and the annual output of 30GWh, was opened in Nova Scotia, Canada in 1984. Also, two small tidal plants were installed in Russia and China with the capacity of 400 and 500kW in 1968 and 1966, respectively [11].

Traditionally tidal energy has been harnessed using a barrage system to establish a head of water, which can in turn power a turbine,

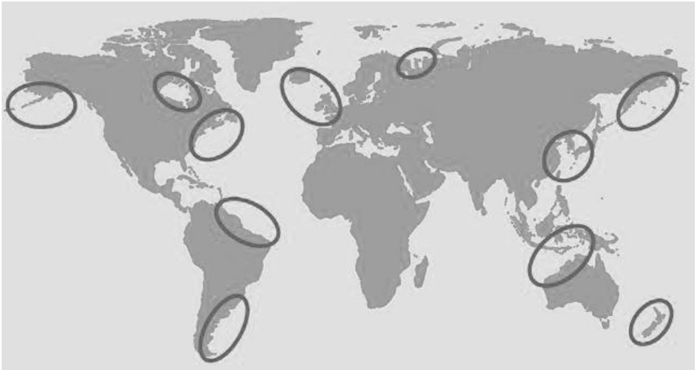

Figure 3. Areas appropriate for traditional tidal power [10]

much as in a hydroelectric dam. The basin is filled through the sluices and freewheeling turbines until high tide. Then the sluice gates and turbine gates are closed. They are kept closed until the sea level falls to create sufficient head across the barrage and the turbines generate until the head is again low. Then the sluices are opened, turbines disconnected and the basin is filled again.

Tidal barrages have the benefit of using well-known technology, but on the other hand they require quite a bit of civil engineering work, the local environmental impact can be considerable, and the number of suitable sites is limited. An example of such a scheme can be seen at the La Rance tidal barrage, Brittany, France. Another way to harvest the tidal current energy is to extract the kinetic energy from the free flowing water, in a sense similar to wind energy conversion. Recent developments in tidal energy devices, TED, have focused on harnessing the tidal stream rather than the potential rise in sea level. Tidal streams are fast moving currents, the speed of which can be magnified by local topographical features such as head- lands, inlets and between islands [12].

Maximum electricity output is thought to be achievable by operating a tidal barrage or lagoon in ebb generation mode, possibly with flood pumping. Generation times could be expected to occur around three hours after high water and continue for around four hours. As a result, a total generation time of just less than eight hours per day could be expected.

Rather than using a dam structure, tidal current devices are placed directly "in-stream" and generate energy from the flow of the tidal current. There are a number of different technologies for extracting energy from tidal currents. Many are similar to those used for wind energy conversion, i.e. turbines of horizontal or vertical axis. There are several ways of categorizing tidal stream devices, with overlap between categorizations. Probably the most obvious design element is the rotor configuration, of which there are three main categories:

- Horizontal axis
- Reciprocating hydrofoil
- Vertical axis.

In addition to rotor configuration, tidal stream devices can be categorized by their placement method, which can be fixed to the sea floor, weighted to sit on the sea floor, or floating (usually through the use of cables attached to land anchors). They can also be ducted, which is a way of concentrating the tidal flows from a larger amount of sea water into a smaller rotor area.

Most tidal currents technologies rely on the horizontal or vertical axis turbine concepts. Turbines may be suspended from a floating structure or fixed to the sea bed. In large areas with high currents, it will be possible to install water turbines in groups or clusters to both drag and lift turbines have been investigated, although the lift devices offer more potential. The concept of installing a number of vertical axis turbines in a tidal fence is being pursued in Canada [13].

Tidal currents are experienced in coastal areas and in places where the seabed forces the water to flow through narrow channels. These currents flow in two directions; the current moving in the direction of the coast is known as the flood current and the current receding from the coast is known as the ebb current. The current speed in both directions varies from zero to a maximum. The zero current speed refers to the slack period, which occurs between the flood and ebb currents. The maximum current speed occurs halfway between the slack periods [14].

TIDAL ENERGY IN IRAN

Iran, with its young population and growing energy demand, its fast growing urbanization, and its economic development, has been one of the countries in the world with high rate of energy consumption and she is well known for her offshore oil and gas industry. Today, concerns

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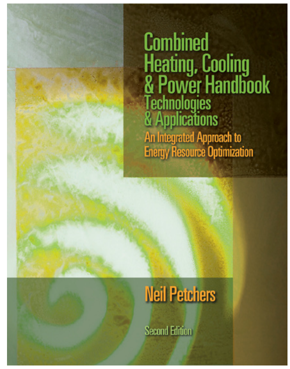

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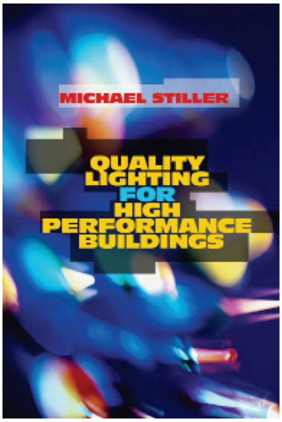

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over global climate change have led policy makers to accept the importance of reducing greenhouse gas emissions. This in turn has led to a large growth in clean renewable generation for electricity production. On the whole, Iran has substantial reserves of renewable energy sources. There is also significant potential for wind and solar power development too. Compared to other forms of renewable generation, tidal energy is extremely regular and predictable and it can be used as an alternative energy for Iran. Iran's geothermal potential is significant in some known locations like in Northwest parts, but only a small portion is considered to be economically feasible. Tidal energy is unique as a renewable technology since it has the capability of providing predictable, firm power contributing to security of supply. Iran is a country endowed with abundant tidal current energy resources. The tidal flows are favorable in southern coasts of Iran such as Chabahar, due to the bay form of the region.

National Cartographic Center (NCC) of Iran has established a number of permanent tidal stations along the coasts of Persian Gulf and Oman Sea during the past 15 years. Also in recent years great efforts have been made by NCC for establishing temporary tidal sites whose collected data have been used for analyzing and predicting of tide for most ports and important places in south coast of Iran. The Hydrographic department of the National Cartographic Center (NCC) of Iran maintains a network of tide-gauges installed at ports located along the Iranian coastline in Persian Gulf and Oman Sea (Figure 4). The network has been set up to measure sea-level variations due to tides; analysis of the data collected by the gauges is used to predict tides. Published by NCC in the form of annual tide tables, these predictions are used extensively by the global seafaring community in operations in the Iranian region [15]. The NCC has made available to the Hydro physic Research Center of Shiraz hourly tide-gauge data collected during 1995–2000 and tide tables data from 2001-2004 at selected stations along the coast. The locations of these stations are marked in Figure 3, as circles; from west to east.

Additionally, electricity can be generated from tidal flows and their kinetic energy by helical turbines in some parts of Chabahar bay such as "Teiss port," "Ab-Shirinkon" and "Kenarak port," and as mentioned above, the generated electricity has diverse usages. Furthermore, it is possible in Chabahar bay to develop the fishery industry with Mashta method making use of the tides. Obtaining energy in a traditional way

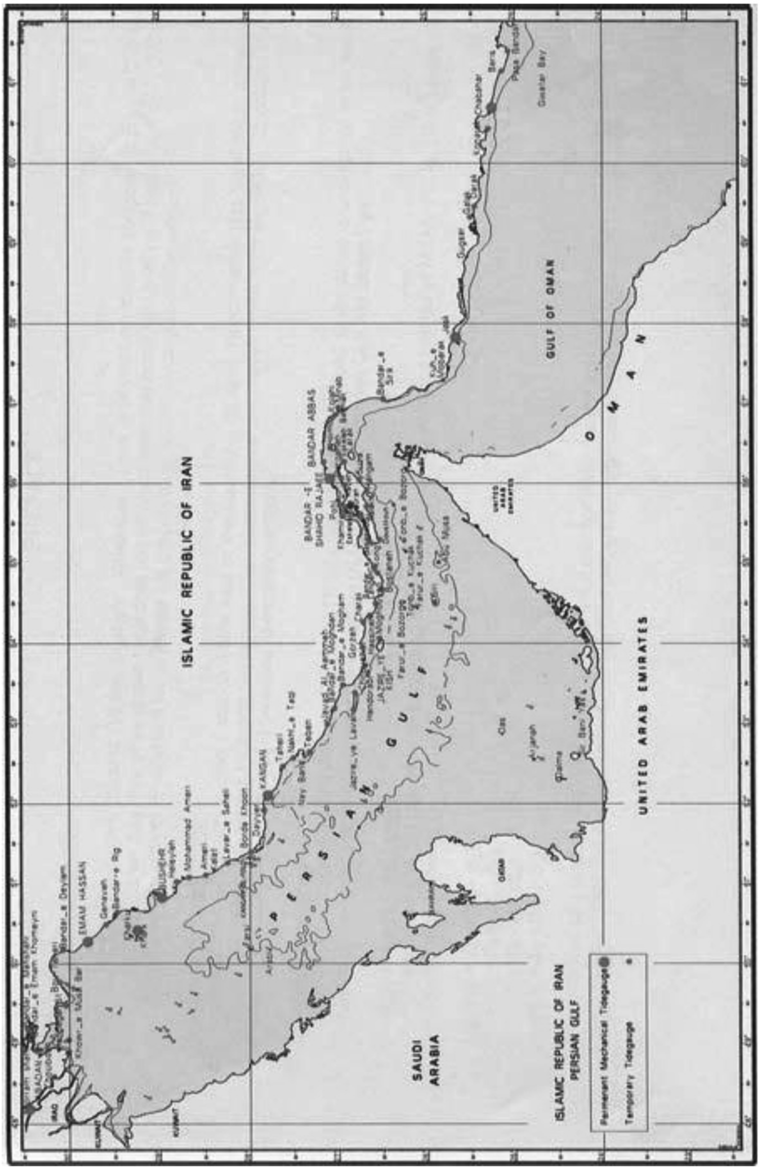

Figure 4. The map shows permanent tidal stations (large red points) and temporary tidal stations (small red points) along the coasts of Persian Gulf and Oman Sea that established by NCC [12].

from tides was initially achieved in Germany in 1580 where using barrages and height difference of the tide, they stirred large water wheels. In its advanced form, acquiring energy from tidal flows has been studied in many countries since 2000. However, no complete and applied research has been carried out in Iran regarding this subject [16].

Iran has a considerable tidal power resource that could be exploited to produce renewable electricity. Although the data is somewhat uncertain, current estimates suggest that its total resource is divided roughly equally between tidal stream and tidal range potential, with a combined output equal to around 5% of Iran electricity supply.

Tidal Potential for in Iran

Tidal Range

Tidal range potential: The global tidal range energy potential is estimated to be about 200 TWh/y, about 1 TW being available at comparable shallow waters. Within the European Union, France and the UK have sufficiently high tidal ranges of over 10 meters. Beyond the EU, Canada, the CIS, Argentina, Western Australia and Korea have potentially interesting sites. Additionally for Iran, there is a wide range of potentially interesting sites for tidal ranges. At present above, tidal barrages operate as commercial power plants, amounting to a worldwide total of 260 MW of installed capacity.

Tidal range cost: Tidal range energy projects require normally higher capital investment at the outset, having relatively long construction periods and long payback periods. Consequently, the electricity cost is highly sensitive to the discount rate used. This problem could be solved by government funding or large organizations getting involved with tidal power. In terms of long term costs, once the construction of the barrage is complete, there are very small maintenance and running costs and the turbines only need replacing once around every 30 years. The life of the plant is indefinite and for its entire life it will receive free fuel from the tide. The economics of a tidal barrage are very complicated. The optimum design would be the one that produced the most power but also had the smallest barrage possible.

Tidal range technologies: The technology required to convert tidal range energy into electricity is very similar to the technology used in traditional hydroelectric power plants. Tidal range energy conversion technology is considered mature, but, as with all large civil engineering projects, there would be a series of technical and environmental risks to address.

Tidal Currents

Tidal currents potential: The global tidal current energy resource is very large. Countries with an exceptionally high resource in tidal or current energy include the UK, Ireland, and Italy, the Philippines, Japan and parts of the United States.

Tidal currents cost: Marine current energy is one of the most promising new renewable energy sources. The know-how is available to combine existing technologies. Marine currents have the potential to supply significant quantities of energy into the grid systems of many countries. As interest grows, marine current energy is likely to play an increasing role in complementing other energy technologies and contributing to the future global energy supply mix.

Tidal currents technology: Recent technologies open up prospects for commercial deployment of some projects in the near future. The economical viability is yet to be proven but it is clear that the production costs will decrease as the technology advances.

Most devices rely on the horizontal or vertical axis turbine concepts. Turbines may be suspended from a floating structure or fixed to the sea bed. In large areas with high currents, it will be possible to install water turbines in groups or clusters to make up a marine current farm. Variants of these two types have been investigated, including turbines using concentrators or shrouds, and tidal fences.

a) Horizontal axis turbines:

This is similar in concept to the widespread horizontal axis wind turbine. Prototype turbines of up to 10 kW have been built and tested using this concept. Figure 5 shows horizontal axial flow turbines.

b) Vertical axis turbines:

Both drag and lift turbines have been investigated, although the lift devices offer more potential (Figure 6). The concept of installing a number of vertical axis turbines in a tidal fence is being pursued in Canada, with plans to install a 30 MW demonstration system in the Philippines.

(a)

(b)

(c)

Figure 5. Some examples of horizontal axis, axial tidal turbines (a) SeaGen[17], (b) OpenHydro turbine[18], (c) AK1000[19]

(a) (b)

Figure 6. Vertical axis turbines: (a) Tidal Fence Davis Hydro Turbine [20], (b) Gorlov helical turbine [21]

For Iran, it seems that the simplest and most economical scheme is the single-pool ebb tide system, because it requires less hydro-mechanical equipment and the turbine is simpler. On the other hand, since Iran's dam construction industry has improved considerably during the 90s, tidal power plants can be developed mainly based on the domestic technology and resources [22].

According to Reference [23], the tidal power values per square meters for six selected location of south coast of Iran can be illustrated in Table 1. Thus, The Bandar-Abbass port, Chabahar port and Khor-e-Musa Estuary respectively are the best locations in the south coast of Iran to establishing a tidal power plant and obtaining energy from tide. Additional establishing a tidal power plant require a large reservoir, and a short and shallow dam closure. In the selected locations, Khor-e-Musa estuary is a natural reservoir but establishing a tidal power plant is impossible, because its inlet need to be dammed-adverse impact on fishing and shipping. In the other selected points establishing a tidal power plant need creating an artificial reservoir [24].

CONCLUSIONS

Tidal energy is one of the most available energies of seas. The main benefits of tidal energy as a renewable energy can be presented as follows:

Table 1. Tidal power values per square meters for 6 selected location of south coast of Iran.

Location of south coast of Iran	Tidal Power Values W/m^2
Khor-e-Musa Estuary	1.1
Bushehr	0.38
Kangan	1.1
Bandar-Abbass	2.35
Jask	0.82
Chabahar	1.93

1. It needs no fuel to maintain, and it's free of charge.
2. Unlike fossil fuel or nuclear plants, it produces no greenhouse gases or other waste.
3. Predictable source of energy (compared with wind and solar), it is independent of weather and climate change and follows the predictable relationship of the lunar orbit.
4. More efficient than wind because of the density of water.
5. It will protect a large stretch of coastline against damage from high storm tides.

Because there is no tide in the Caspian Sea in the northern part of Iran, the researchers focus on the southern Coast of Iran: the Persian Gulf. In this article, the distribution of tidal current energy and the future potential of tidal energy in Persian Gulf were presented.

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ABOUT THE AUTHORS

Mofid Gorji-Bandpy, PhD. Eng. Education: PhD: School of Engineering, Division of Mechanical Engineering, University of Wales College of Cardiff (UWCC), Cardiff, UK 1987-1991.

Affiliations and functions: Full time Professor, Department of Mechanical Engineering, Noshirvani University of Technology, Babol, IRAN (Since 1979), Visiting Professor, Department of Mechanical and Industrial Engineering, University of Toronto, Canada and Coordinate Supervisor, University of Guildford, Surrey, U.K., (Since 1997).

Research interest: Renewable Energy, Propulsion Systems, Fluid Mechanics, Turbomachinary

Publications: Author of more than 200 scientific articles and 5 text books.

Mohammadreza Azimi, Eng. Education: 2004-2007—National Organization for Development of Exceptional Talents.

2008-2012–B.Sc Graduated from Department of Mechanical Engineering, Noshirvani University of Technology, Babol, IRAN

2012—Msc. Faculty of Engineering, Tarbiat Modares University, Tehran, Iran.

Affiliations and functions: Faculty of Engineering, Tarbiat Modares University (TMU), Tehran, IRAN.

Research interest: Renewable Energy, Turbomachinary and Propulsion Systems

Publications: author of 10 papers.

Mohsen Jouya, Eng. Date of birth: 1990.

2008–Department of Mechanical Engineering, Noshirvani University of Technology, Babol, IRAN

Affiliations and functions: Department of Mechanical Engineering, Noshirvani University of Technology, Babol, IRAN

Research interest: Renewable Energy, Analytical Methods, Applied Sciences

Publications: author of 4 articles and 1 conference presentation.