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Analysis of characteristics of Dynamic Tidal Power on the west coast of Korea

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ABSTRACT

Korea has developed various new and renewable energy resources since 2000 due to increasing demand for Green Energy around the world. Because the west coast of Korea has an extreme tidal range, many research projects aimed at harnessing tidal energy have been conducted there successfully. Though the study of Dynamic Tidal Power (DTP) was started as a new tidal energy source about 20 years ago, its characteristics are not yet fully understood. DTP has the potential to have less environmental impact than does a conventional barrage type tidal power generator. Its characteristics were analyzed in many test cases using a numerical model. The theoretical maximum tidal power of DTP became the same as the maximum tidal range by controlling the phase difference. This showed that DTP has great potential for a very successful future in the Yellow Sea. Moreover, DTP could provide an attractive energy source even in areas of lower tidal range than indicated in previous studies.

1. Introduction

Energy availability has become a major issue in every country, and demand for renewable energy has been increasing around the world due to climate change and other issues related to fossil fuels. Though the Korean government has relied too much on fossil fuels and nuclear power, they are still popular due to the current economics of alternative energy options. However, Koreans have been interested in various marine energy sources even before the beginning of the current global energy crisis.

Because Korea has one of the most extreme tidal ranges in the world, many technologies have been developed for utilizing tidal energy. There are currently four different tidal power systems: tidal barrage generation, tidal stream generation, Dynamic Tidal Power (DTP), and tidal lagoons [1]. The tidal barrage generates power using a closed, dam-like structure, whereas tidal stream generation involves a kind of underwater turbine. Tidal barrage generation has long history and the first such system was built 50 years ago. The representative examples are the Rance Tidal Power Station in France and the Sihwa Tidal Power Plant in Korea [2–4]. Various effects of the tidal barrage, including environmental issues, were evaluated over 40 years of operation at the Rance Tidal Power Station [5]. The characteristics of the tidal barrage and the tidal stream were explained and compared. The tidal stream has fewer environmental issues than the tidal barrage, but its impacts still need further investigation [6].

The DTP and the tidal lagoon are new and alternative tidal power systems. DTP is similar to the tidal barrage but its structure is open from coastline to offshore. The tidal lagoon involves building a closed artificial lagoon and then generating power through a turbine at its outlet. The first such construction will be started in Swansea Bay and the environmental effects have been reviewed [7,8]. The details of the proposal for the tidal lagoon in Swansea Bay were explained [9]. Various tidal power generation scenarios, considering costs and environment issues were introduced, and the existing and future tidal-range turbines were compared [10].

The recent trend in tidal energy research has been focused on developing new turbines or increasing their efficiency. Though conventional barrage-type tidal power has been proven at the Rance and Sihwa tidal power plants, such systems are still very expensive and suffer from multiple environmental issues. A secondary problem is its tidal range requirement. Such a system should be located in a basin or gulf where the tidal range is higher than 7 m and the tidal cycle is semidiurnal [11]. Because only a few sites around the world satisfy these requirements, the tidal barrage cannot be widely accepted. Because little progress has been made in related research, many tidal barrage projects in the United Kingdom are either awaiting approval or have been rejected. They found alternative ways such as building a tidal lagoon instead of using a tidal barrage [12]. Korea has also been faced with the same restrictions and most of the tidal barrage projects proposed in Korea were rejected.

The impacts of the tidal barrage were also studied. The impacts of tidal power systems on water quality (e.g., sediments, salinity, dis-

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Table 1
Comparison of Korean tidal barrages.

	Name of Tidal Barrage			
	Sihwa	Ganghwa[a]	Incheon[a]	Garorim[a]
Location	37.3°N 126.65°E	37.7°N 126.3°E	37.55°N 126.5°E	36.9°N 126.35°E
Power Output Capacity (MW)	254	840	1320	520
Maximum Tidal Range (m)	9	7.7	7.7	6.8
Length of Dike (Km)	12.7	7.7	17.0	2.1
Sea Area (Km^2)	39	79.4	157.5	96

[a] Ganghwa, Incheon, and Garorim are planned.

solved oxygen, and nutrients) have been reviewed via numerical modeling [13]. The salinity and suspended sediment were decreased by the tidal barrage but the dissolved oxygen was unlikely to be impacted [13]. The hydrodynamic variations of the tidal barrage at the Severn Estuary were investigated using a numerical model, and the maximum discharge and the maximum water level upstream of the barrage were decreased by 30–50% and 0.5–1.5 m respectively [14].

The most important factor of the tidal stream was the flow speed, and the tidal energy was proportional to the cube of the flow speed. High tidal range was not necessary for the tidal stream, because the flow speed was also affected by geographical condition. Whereas the tidal barrage needed a large structure, the tidal stream was small so its environmental impact could be reduced. However, the size of tidal stream facilities has been increased recently, so its impacts have also been studied. Most of studies have been focused on developing a new, more efficient turbine, but this was still low compared with other methods [15]. Multiple installations of turbines were considered to increase the generating capacity and each turbine should be located five rotor diameters away from each other [16]. This could cause impacts

Fig. 1. Location of Sihwa Tidal Power Plant in Korea and the shape of its barrage structure.