

Summary

This document gives a first approach towards site selection for in-stream hydro energy generation sites. It does not aim to be a complete manual, but outlines the rough step plan and details basically needed to assess and develop a in-stream hydro site.

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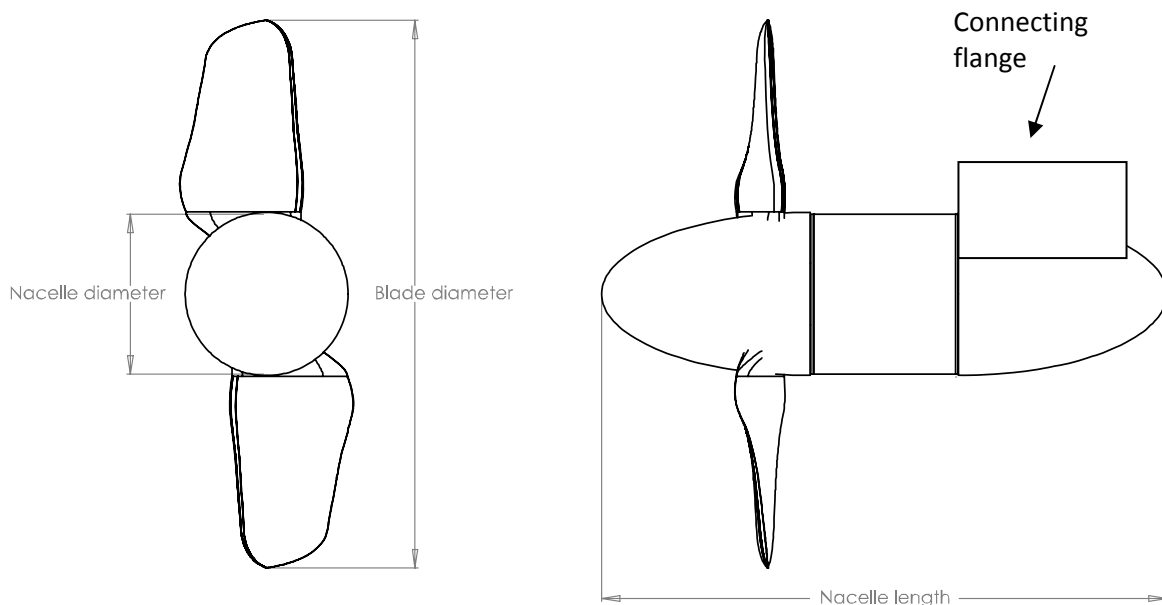
1. Technology summary

1.1 Turbine series

Tocardo’s T-series of turbines currently come in three sizes: the 50kW “T50” turbine, the 150kW “T150” unit and the large 500kW “T500” offshore and deep water unit. Turbine blades can be accommodated to operate at different flow speed conditions, currently the optimum for the T-series is reached at 3.5 m/s water speeds. Turbine dimensions and basic requirements given in the tables below are based on this condition.

1.2 Turbine general dimensions

All Tocardo T-series units basically look the same but physical size is different. In general the layout is as follows:



Connection to the foundation is through the indicated flange position, which can point either up or down.

The table below gives typical dimensions and weights of the turbines.

	Blade diameter [m]	Nacelle diameter [m]	Nacelle length [m]	Nacelle weight [ton]
T50	2.8	0.94	3.65	3.0
T150	4.5	1.30	4.65	9.0
T500	8.4	2.80	11	20

Scope of delivery is turbine nacelle, turbine blade, control cabinet and remote (web) operation interface. Extra’s like cabling, foundation and site engineering services can be supplied by Tocardo when required.

1.3 Turbine to foundation loads

Turbine forces go with the square of the velocity; twice the flow speed gives four times the forces. The operational loads are given in the table below, for nominal (3.5 m s^{-1}) conditions. Peak loads lie generally 50% higher.

	Operational axial load [kN]	Maximum axial load [kN]	Operational torque (= max torque) [kNm]
T50	30	45	11
T150	100	150	35
T500	300	450	110

1.4 Site requirements per turbine

Minimum site conditions for turbines are given in the next table. In general, the deeper the water, the more clearance for overhead and bottom transported debris, shipping and surface waves is obtained. At least 1.5 to 2 times the rotor diameter should be kept as minimum useable water depth.

Optimum vertical turbine positioning in the water column depends on the site, but is generally somewhere just above the middle of water depth.

	Blade size [m]	Min water depth [m]	Min water speed [m s^{-1}]	Nom. water speed [m s^{-1}]	Nom power output [kW]
T50	2.8	> 4.2	2	3.5	50
T150	4.5	> 6.8	2	3.5	150
T500	8.4	> 12.6	2	3.5	500

1.5 Array configurations

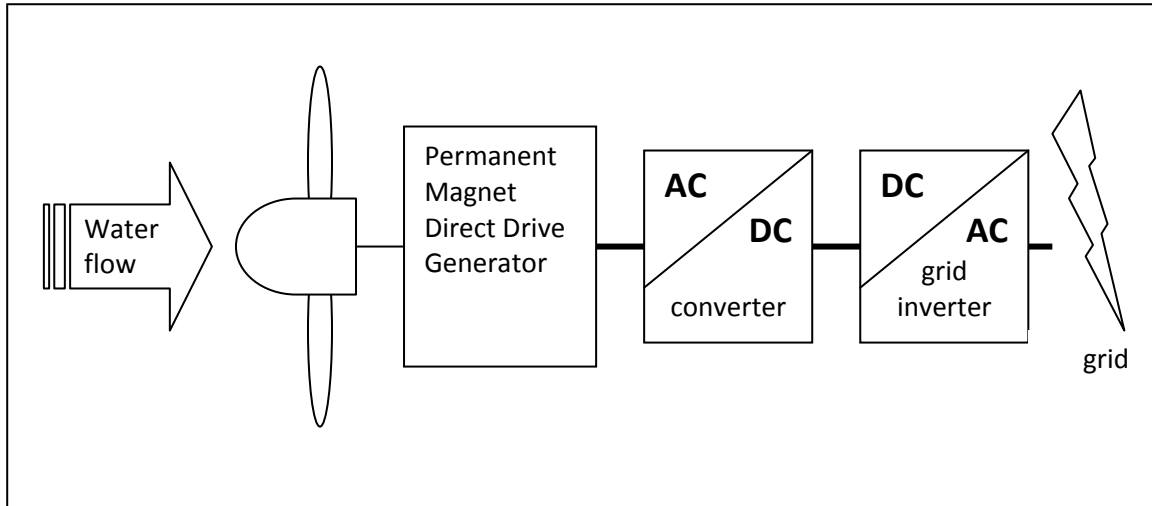
The optimum multi-turbine configuration needs to be established on a site-by-site basis. According to the current insights, turbines are best organised in “rows”. Unlike wind, tides and river streams come from defined directions, therefore turbine spacing can be tight and organised for optimum energy efficiency. A “farm of turbines” therefore looks different from a wind farm development though. Universities all over the world are busy with optimisation projects, Tocardo is connected to a few of them. Insights will be updated as the market progresses.

For now, the following “rules of thumb” for array configurations can be taken into account:

- Horizontal turbine centre-to-centre spacing: > 1.5x D
(= 1.5 times blade diameter; e.g. a 4.5 metre turbine requires a spacing of 6.75 metres).
- Lateral “row” spacing: >30x D
(= 30 times blade diameter; e.g. a 4.5 metre turbine requires a row spacing of 135 metres. Spacing can be tighter though, but energy in the flow is not fully “recovered” by then).
- Vertical “stacking” of turbines (in layers)
In case of very deep water, it can be considered to put multiple turbines “on top of each other” vertical in the water column. However, for first projects, it is considered wise to limit the development to single layer developments only.

1.6 Schematic Power Take Off (PTO) system layout

The picture below gives a block diagram of the turbine system layout, with a focus on the PTO system.



Power output from the power conversion units are directly fed into the grid, standard being 400V three-phase, 50/60Hz (selectable). Other types of grids can be accommodated for, by simple choice of grid inverter units (standard off shelf components).

Multi-turbine array configuration can be accomplished by DC bus coupling or separate stand-alone AC-DC-AC conversion units per turbine system, coupling on the grid (AC) side.

Higher transmission voltages can be accomplished by using step-up transformers.

1.7 Typical site layouts

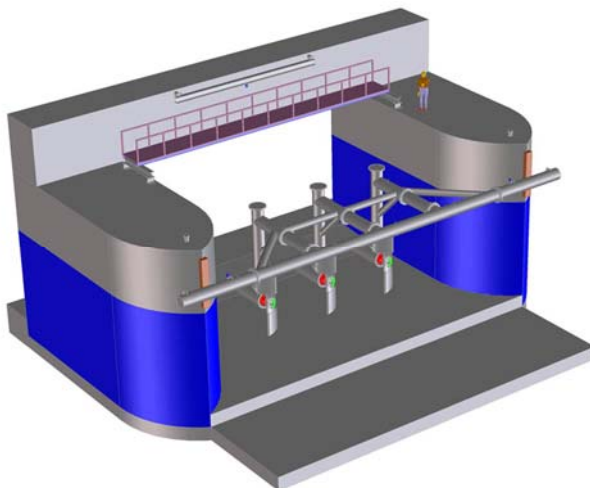
Constructions to connect turbines “to the world” vary per site. Typical installations and constructions developed so far are presented below, to give a general impression of possibilities.

1.7.1 Den Oever site, the Netherlands

T50 single turbine installation, operational since summer 2008 in the Stevin sluices of the Afsluitdijk barrage in the north of Holland.

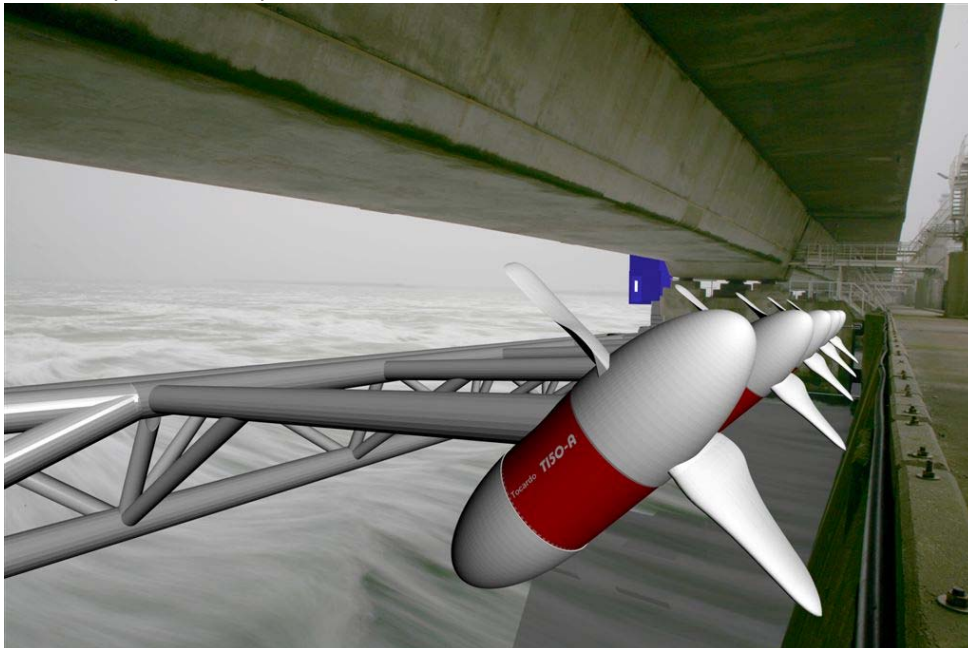


Triple T50 turbine installation, based on same site as the above single turbine installation.



1.7.2 Oosterschelde site, the Netherlands

5x T150 turbine installation in the Oosterschelde storm defence in Zeeland, The Netherlands
(will be operational by the end of 2010)



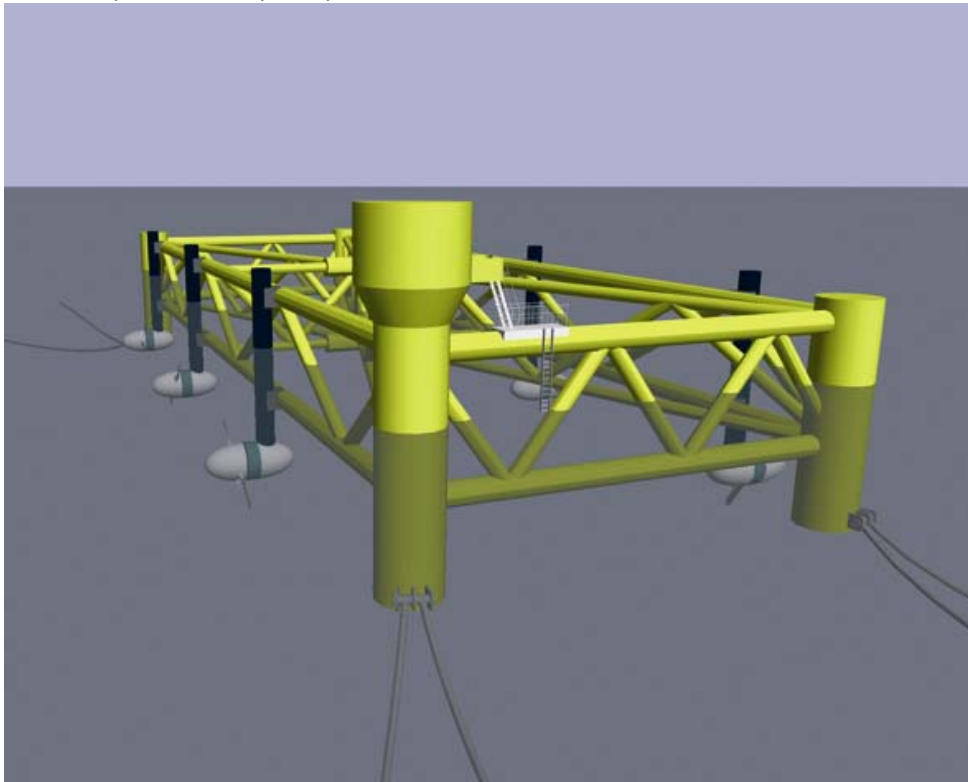
(picture: turbines lifted up)



(picture: turbines in operational position)

1.7.3 Texel site, offshore floating platform

6x T150 turbines in offshore conditions in the Waddenzee, near the Dutch island of Texel.
(will be operational by early 2011)



1.7.4 Offshore gravity based farm installation

Typical applications in deep water offshore sites. First installations expected by early 2012.
##picture to come soon

2. Site selection & development

2.1 Quick step plan

The rough step plan for site selection is as follows:

2.1.1 Step 1 - site definition

- Fast flowing water? (> 2m/s)
- Desire to generate electricity?

2.1.2 Step 2 - turbine choice

- What type of water?
(river, hydro, tidal, uni- or bidirectional, etc)
- What speeds?
- What water depth?

2.1.3 Step 3 - site economy

- How often does water flow?
(statistics; histogram of velocities over representative period of time)
- Bridge or other construction to hook turbines onto nearby?
(or do we need to create a separate foundation?)
- Grid nearby?

2.1.4 Further details

See the table on the next page.

2.2 The full details

The full list of information needed to describe a site is in the table.

Site	
Site	Resource
	Type of resource (tidal, river, post-hydro, other)
	Water depth
	Energy content (histogram of velocities over representative period of time)
	Water quality (debris, turbulence, salinity, waste)
	Geophysics & foundation options (bridges or other structures to hook up, soil condition)
	Storm conditions & wave climate
	Environmental
	Other water users
	Local issues: <ul style="list-style-type: none"> • Influence on tides / currents • Influence on sand / sediment transport • Special care for charismatic megafauna, etc
	Environmental regulations (EIA requirements, endangered species, etc)
	Consenting
	Local policies & politics
	EIA requirements / SEA framework?
	Business climate
Local contractors	
Deployment / production sites	
Service & support parties	
Grid	
Type of connection (grid, off-grid, hydro)	
Nearest grid feed-in point	
Grid voltage	
Grid capacity	
Grid operator	
PPA	
Finance	
Energy tariffs	
Incentive schemes <ul style="list-style-type: none"> • Carbon offset? • Subsidies? • Feed-in tariff? • Tax incentives? • PR purposes? 	
Other instruments	