The Mill
Brimscombe Hill
Stroud
Gloucestershire
GL5 2QG
Tel. 01453 887744
Fax. 01453 887784

info@renewablesfirst.co.uk
www.renewablesfirst.co.uk

Ramsgate Harbour

Hydropower Feasibility Study

Ref:	Issue:	Date:	Written by:	Reviewed by:
RAMSG_HFS1	01	10/10/2014	JS	RR

Contents

Site Details & Resource

Introduction

The purpose of this report is to summarise the findings from the site survey, propose the most suitable hydropower system for the site and to provide energy capture and income estimates for the system. Recommendations are made to detail the further work that need to be carried out if the project is moved onto the next stage.

Purpose of Scheme

The purpose of the proposed Ramsgate Harbour scheme is to utilise the existing harbour infrastructure to provide a renewable source of electricity to the port and surrounding area. This project will act as a pilot scheme, with a view to setting the president for future projects in similar locations.

The project will for fill two policies stated within 'The Port Ramsgate's Environmental Practice Statement' (Version 1.0), by providing the harbour with an innovative source of renewable energy (reducing the carbon footprint of the harbour), and providing a source of revenue.

Existing Infrastructure

Ramsgate is located on the southeast corner of the Isle of Thanet, facing the English Channel. Positioned to the northeast of Ramsgate's Port and outer breakwaters, the harbour is enclosed by the block stone East Pier and West Pier. A Crosswall spans between the two piers, consisting a disused dry-dock, seven sluices, and a tidal flap gate and lock arrangement at mid-point (see Figure 1 below).

Proposed by John Smeaton, the Crosswall was built in 1871 with the purpose of retaining tidal waters in an inner harbour area of approx. 46,000m^2. The waters retained at high tide could be directed at low tide through the sluice gates located at intervals along the Crosswall to displace silt build-up within the outer harbour. Measuring approx. 3.6 m by 4.2 m tall, the sluice tunnels have bases approx. 0.4 m above Chart Datum (-2.18 m mAOD). Tunnels 3 to 5 have since been sealed by blockwork on the outer harbour face and are inaccessible. Sluice tunnels 1-2 and 6-7 have been sealed mid-length by concrete bag/geotextile membrane arrangement at the sluice gate position (see Appendix 2).

The Crosswall now hosts a lifeboat station, fuelling station and boat hoist, and disused hover-pad. The inner harbour supports a marina with approximately 400 berths. The flap gate is raised to retain a minimum marina water level of approx 3.4m CD. The gate is lowered approximately 2 hours before high tide and raised approximately 2 hours after high tide, providing boats with a 4 hour access window to the Marina. A small rising bridge, spanning the lock gate allows pedestrians and vehicles circular access when the flap gate is closed. The landowner and port authority is Thanet District Council.

Referring to British Geological Survey records, the Crosswall is footed on a chalk rock head of the Thanet Formation. In the harbour, the rock is overlaid with a superficial layer of beach and tidal flat deposits, (see Appendix 5). Levels are given in both Chart Datum (mCD) and Ordinance Newlyn (mAOD). Photos of the site are included in Appendix 1.

Location

Site	Ramsgate Harbour
Nearest major town/city	Ramsgate
Easting	63855
Northing	164609
OS grid reference	TR 38355 64609

Hydraulic Head

Date	Gross head Measured (m)	Description
10.09.14 (Spring tide)	5.08	Water level difference between low and high tide

Tidal waters retained within the Inner Marina behind the flap gate generate the head difference between the Inner Marina and outer harbour, as the tide ebbs in the outer harbour. The two points where the head was measured between are shown in Figure 1 below. This has been compared with water level difference provided by a tidal harmonic model. Given the close correlation, and that the site is in direct proximity to the sea with minimal funnelling effects, it has been assumed the harmonic model will be accurate enough for the study. The complete set of levels taken during the site survey can be found in Appendix 3.

Averaged Tidal Range (m)		
Spring	Average	Neap
4.6	3.6	2.6

The Tidal range refers to the tide range across the site, measured between high water and low water. For the study, data is presented so that 'Spring' levels refers to the average spring tidal level across 3.5 days where the tide range is at its greatest. 'Neap' levels refer to the average levels during the 3.5 days where the tidal range is at its lowest and the Average levels refer to the 3.5 days each side of any Spring or Neap period of a tidal cycle. Therefore in a 14 day period, Spring and Neap portion of tides will occur and two Average portions of tides will occur. This simplified tidal model will allow the energy capture to be modelled to a good degree of accuracy. Additional modelling would take place in the Outline Design stage.

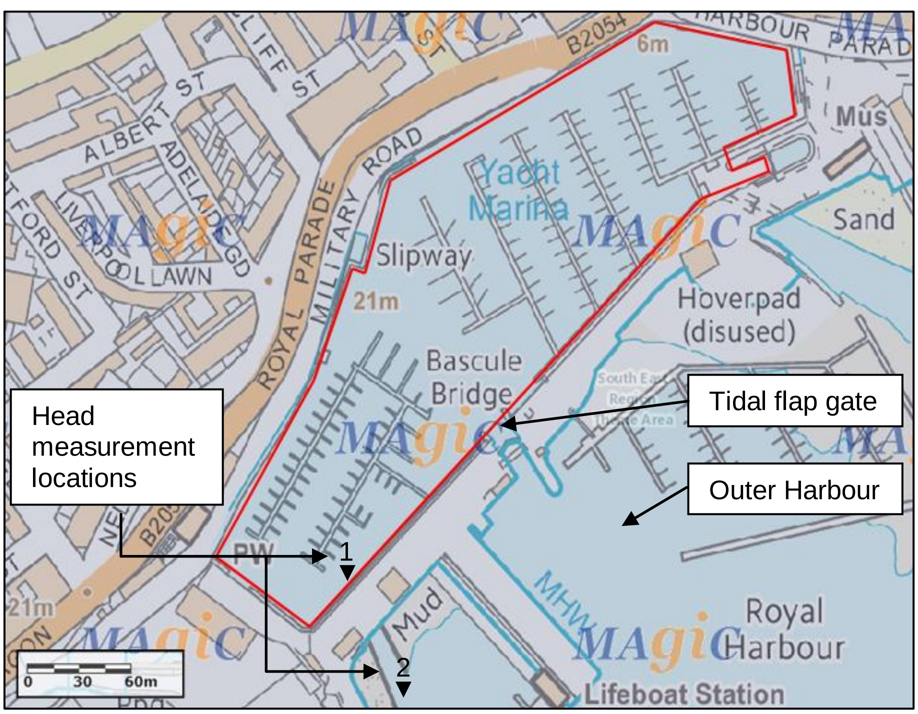


Figure 1 – Extent of Inner Marina (indicated by red line)

Flow available at Site

The retained water can be released through a sluice gate until the water level within the Inner Marina reaches 3 mCD (0.42 mAOD), as specified by Client, which allows boats clearance above the Inner Marina bed level. Here, boats and pontoons displace water within the marina and reduce the volume of water stored at any high tide.

	Usable Volume m^3	Usable Volume after displacement m^3
Spring Tide	101,200	99,017
Average Tide	73,600	71,417
Neap Tide	46,000	43,817

Table 1 – Usable storage capacity of the Inner Marina

Environmental Consideration

The site has been checked for environmental designations that could affect the construction of a hydroelectric system. It appears that the site is not subjected to special protections.

Ramsgate harbour is a historic site, and as such there are listed buildings and features. The dry docks and Crosswall are Grade II* listed. On the Crosswall, the sluices, bollards and lockgates are also grade II* listed. Therefore, consideration will need to be taken in the outline design stage to mitigate any changes to listed structures. The environmental designations map is shown in Appendix 4.

Grid Connection

There are two 11 kVA substations located within the vicinity of the proposed scheme. The closest (reference number 34-3341) is located approximately 90 m southwest of sluice #1 in the nearby boat park (OS grid ref. TR382643), see Appendix A1.7. The second substation (reference number 34-2501) is located 150 m from the proposed site on the east side of the Crosswall (TR383645), see Appendix A1.8. Connection permission would be required from the UK Power Network, the Distribution Network Operator (DNO), who would assess the capacity within the existing network.

At this stage, it is envisaged that a connection can be made at the location of the transformer without upgrade. This has been determined by gaining an estimate from the DNO.

Access

The site lies within 23 miles of the M2, junction 7. The vehicular route enters Ramsgate via the A299 , and follows onto the B2054 (Royal Harbour Approach) until reaching the roundabout on the Royal Parade. From here, a vehicular approach involves a following single track B road (Military Road) around the Inner Marina for 400 m onto Weir Pier, passing the Royal Harbour Marina and Port Authority building. Access from Ramsgate Port is via Military Road from the west. On the Crosswall, Sluice tunnel 1 passes under a car park, between the West Amenities building and adjacent Dock Master's building.

Pedestrian access, down the Crosswall steps to the outer harbour entrance of sluice tunnel 1 is limited to low tide. Access to the Inner Marina entrance of the sluice tunnels is limited to divers only, as the tunnels are submerged by water the retained in the Inner Marina.

There is a moderate flow of pedestrians across this site. An appropriate traffic and access management plan, involving liaison with the Harbour Master, would be needed to ensure public safety and minimise disturbance to the normal running of the harbour.

Proposed Hydropower System

Location and General Specification

Layout

Based on the possible head and flow, and the ground conditions, a titled axis propeller-type VLH turbine is recommended for the site. This provides the flow control required, whilst reducing excavation into the bed rock and a reduced the project footprint. The preferred location for the turbine is in the outer harbour, in front of sluice tunnels 1 and 2, to effectively use them both as penstocks (see Figure 2 below).

Approximately 3.2 m in diameter, the turbine will require a power house foot print of approximately 9 x 20 m long. A section of the existing channel will need to be excavated to accommodate the turbine sump (see Figure 3 below). This will involve installing a temporary cofferdam around the site to prevent tides in the outer harbour from affecting construction.

Upstream, in the marina, a second smaller cofferdam, possibly in conjunction with stop logs, will be erected in front of tunnel entrances so the tunnels can be pumped dry. This will allow the breakout of the concrete cap, bulk head and old sluice gate inside. The stop logs would allow the tunnel to be sealed and inspected after construction. It has been assumed that the marina basin will be dredged of silt prior to the commissioning of the hydro system.

The power house structure will be of reinforced concrete, incorporating an intake screen to prevent trash and other debris fouling the turbine. Here, a sluice arrangement will isolate the turbine and allow the manual release of water and debris during maintenance. A second screen positioned downstream will prevent public access into the sump. An excavation 3 m deep will be needed to construct the sump and inverted spillway. At high spring tides the turbine will be completely submerged (see Mean High Water Spring) and the tail race is submerged throughout all tidal cycles ensuring the turbine is fully flooded throughout any operational cycle. Silt build up in the sump will be flushed through as part of the annual maintenance schedule (see Turbine and Related Hardware section).

The turbine and civil works will be exposed to high levels of corrosion from the salt water environment. An arrangement of sacrificial anodes will provide cathodic protection of metal components against corrosion.

The turbine will be connected to the national grid by a 90 m long cable following the face of the West Pier to an existing cable channel leading to the Boat Park sub-station. An alternative 140m connection into the Dock Master's distribution board will allow the electricity to be consumed on-site before export.

Figure 2 - Proposed Turbine layout (tail race excavation is shown in magenta)

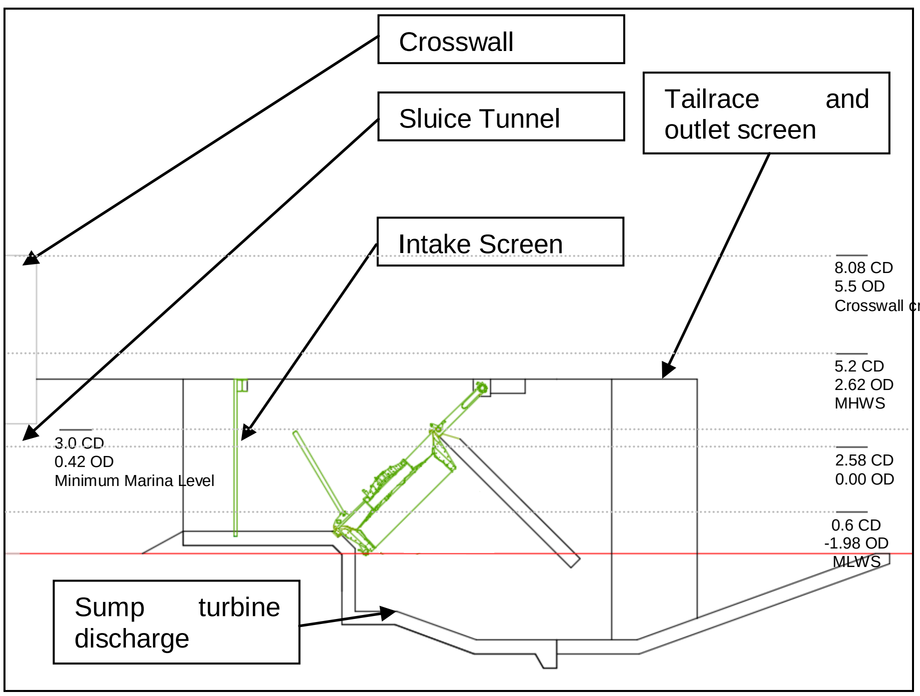


Figure 3 – Section A

Head

Maximum impounded head is achieved by holding the retained water within the Inner Marina, and only releasing this water through the turbine once the outer tide level has fallen to near low tide level. To make use of this potential energy, a high flow rate is needed to discharge all of the available volume within this 'maximum head' window, which is 0.85-2 hours, either side of low tide, depending on the tide range on any given day. By placing the turbine outlet below Mean Low Water Spring (MLWS), the highest head range can be achieved.

The installed turbine is unlikely to operate across the full tidal range as generation would have to start before low water level was reached to ensure a lengthy generation period.

	Max Head (m)	**Average Head (m)**	**Min Head (m)**
Spring Tide	3.73	3.13	1.46
Average Tide	3.08	2.6	1.67
Neap Tide	2.43	2.06	1.52

Table 2 - Maximum, minimum and average gross heads for the three tidal models

The turbine selected needs be able to operate efficiently at these head ranges and be able to control the flow because a near constant electrical output is desirable. The net head assumes 10 % losses at rated flow; all system hardware has been selected to stay within this limit.

Flow Rating of System

The turbine has been sized to ensure the power output of the system does not exceed 100kW, keeping it within a higher Feed in Tariff banding. This will be achieved through careful regulation of the flow through the turbine. The turbine also needs to pass the necessary flow to achieve a near constant power at the low head which occurs at the end of each cycle.

The turbine has been oversized for the scheme and will only ever be running at 50% capacity. However such a large turbine is necessary to accommodate the high flow ranges required.

Run Time

The average daily run time is the culmination of turbine operations over the course of a day. On average there are two tidal cycles per day approximately 12.5 hours apart. Therefore, the turbine will operate at all hours of the day over the course of a year. The runtime and discharge have been tailored to ensure the turbine is operating at the highest head over the full range of tidal cycles avoiding an excessive discharge rate, which would require an even larger turbine. Table 3 shows the run time per tidal cycle for the constant discharge, required to release the retained volume during the period of highest head.

	Average cycle runtime (h)	**Average Daily runtime (h)**	**Constant Discharge m^3s^{-1}**
Spring Tide	4.00	8.00	6.88
Average Tide	2.86	5.72	6.94
Neap Tide	1.71	3.42	7.12

Table 3 - Run time per tidal cycle for the three tidal models

Marina Operational Window

The window in which boats can enter and exit the inner harbour currently covers a 4 hour span, 2 hours before and 2 hours after high tide. To achieve maximum head the flap gate must be closed at high tide, this halves the marina operational window to only two hours but results in a high energy capture (see Figure 4). If the marina operational window is to be kept at its current schedule there is a much smaller energy capture as there is a lower volume of water available to the turbine at a lower average head.

If the longer marina operational time is crucial then a compromise could be achieved. During Neap tides the marina could be accessible for the usual four hours. During spring and average tides the marina operational time would reduce to 2 hours to make use of the high potential for energy capture. This would reduce the energy capture by 5-10%.

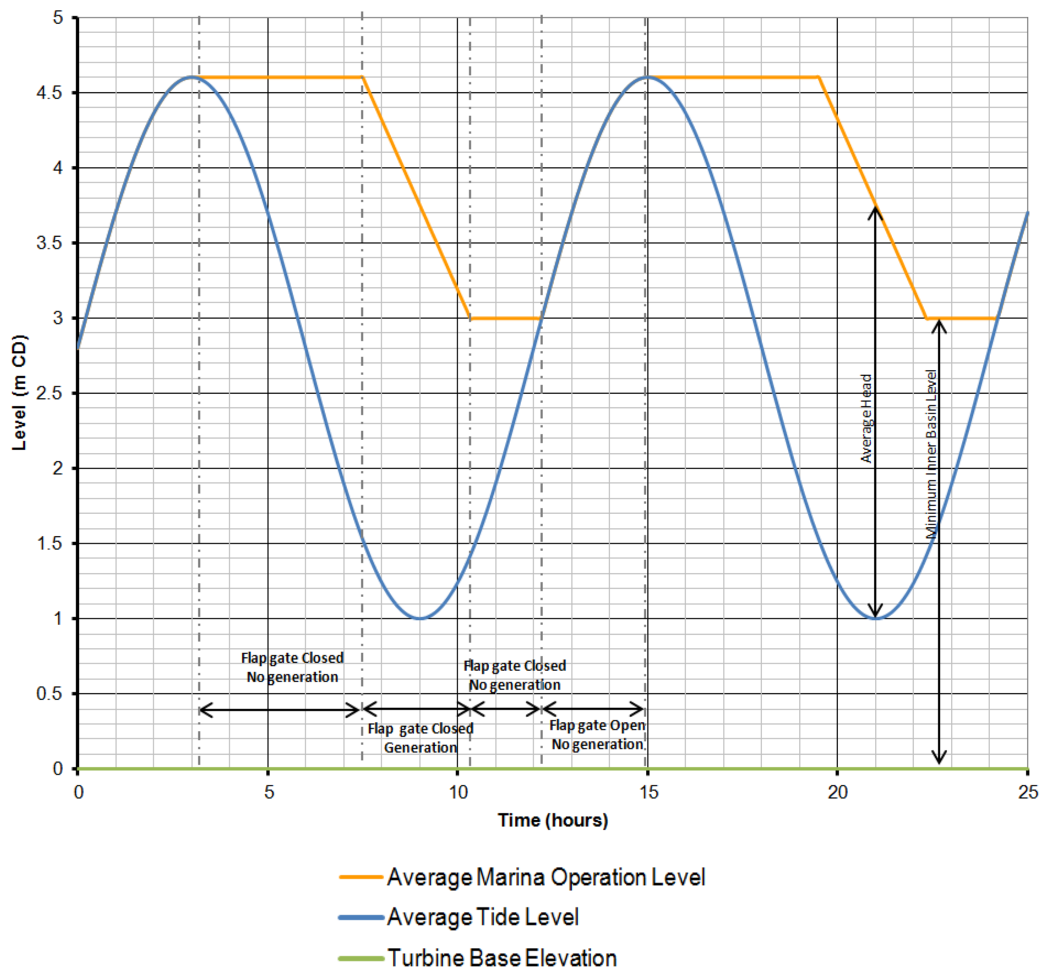


Figure 4 – Average operational cycle for optimised flow

For the study, it has been assumed that the flow rate through the turbine is constant, hence the linear relationship between Level (m CD) and Time (h) displayed in Figure 4 during the generation period. In reality, to maintain a near constant power output, the control of the discharge rate by the turbines' control systems will be non linear. The modelling of the discharge rate in relation to the head, runtime and power output, as previously discussed, will be modelled in subsequent design stages to get a more precise energy capture.

Turbine and Related Hardware

Turbine

The VLH turbine is a propeller type turbine but with a large runner and slow rotation speed. The flow is axial, rather than radial, and regulated only by the runner blades. It is specifically designed to be installed into an existing channel with minimal civil works. The generator is fitted directly to the runner in a sealed hub and so it has no drive efficiency loss. The whole unit can be pivoted in and out of the water to allow maintenance of the turbine or for sluicing. The slow rotation speed makes it less likely to harm fish, and VLH have published research showing that eels can pass without harm, although this may not be accepted by the Environment Agency or Natural England without independent verification. A section of the VLH turbine is shown below.

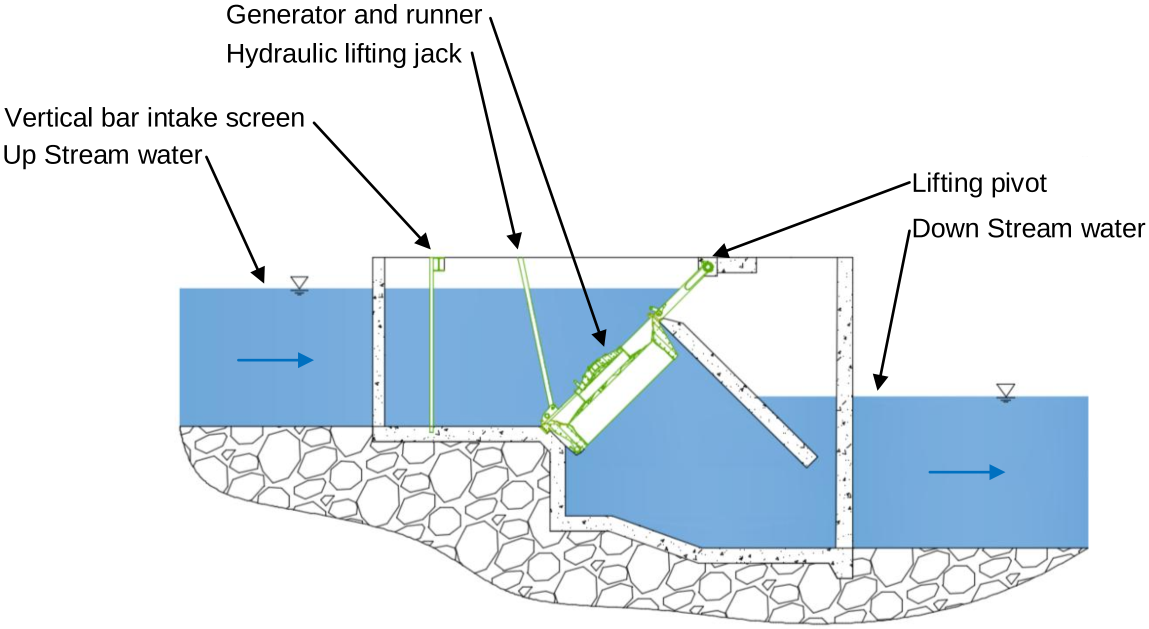


Figure 5 – Cross section of typical VLH Turbine installation

The VLH Turbine is typically operated in head ranges from 1.5 m - 4.5 m, covering flows up to 27.0 m^3s^{-1}. This operation range requires a large bulky turbine, with runner diameters ranging from 3.2 m – 5.0 m. The power output varies from 100 kw – 500 kw but installation of several smaller units can often be more profitable than one large unit. Over the course of the operational flows the efficiency of the VLH fluctuates between 74 -75%.

A VLH turbine has yet to be installed in a salt water environment. However the manufacturer has included in their budget quote upgrades to the materials and seals as well as appropriate cathodic and paint projection. A maintenance guide for the ‘seaworthy’ VLH has been provided (see Appendix 6).

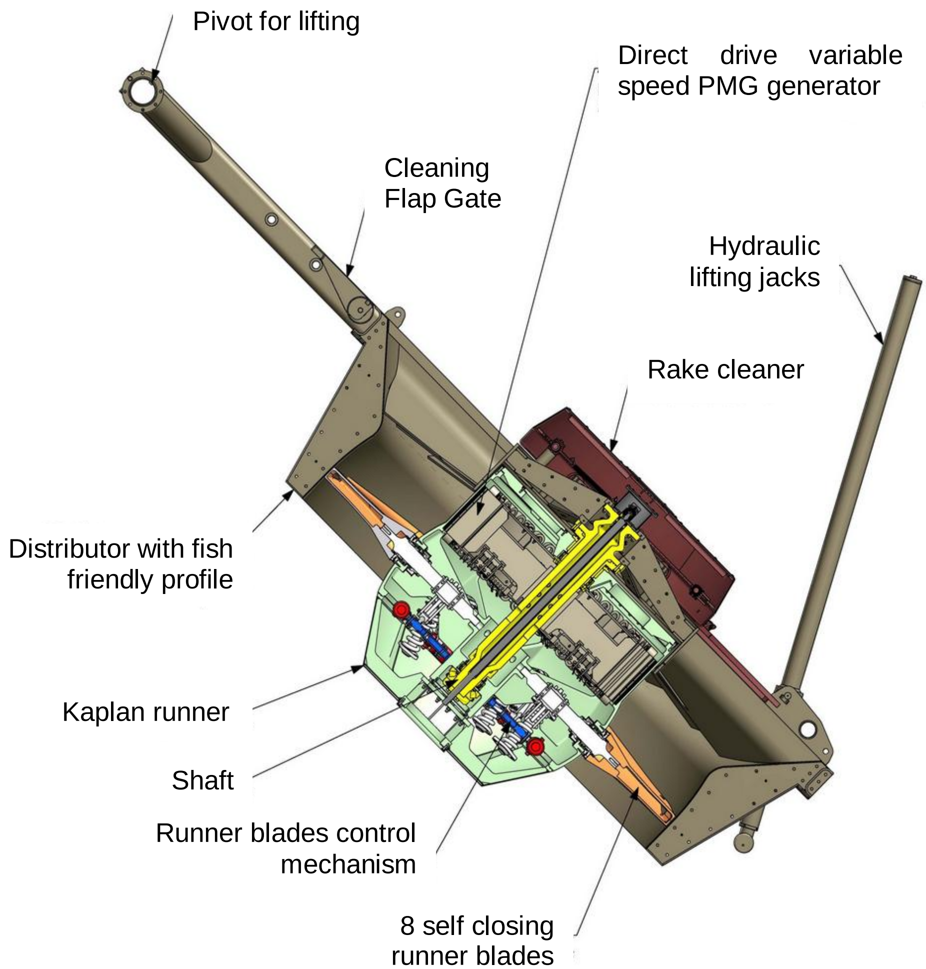


Figure 6 – Cross section detailing typical VLH Turbine configuration

Penstock

The penstock takes the impounded water to the turbine. Approximately 30 m in length, the penstock is made up of the existing sluice tunnels 1 and 2, and a proposed cast in-situ concrete reducer channels the flow into the turbine. The two sluice tunnels running parallel through the harbour wall have a combined cross sectional area of 25.9 m^2 and may need sealing with a layer of spray of concrete, or similar protector, if water percolation was a deemed risk to the masonry structure.

Figure 7 - An existing VLH installation with a dual tunnel penstock.

Screening

Hydropower systems are screened in order to both protect the mechanical hardware from debris and to protect fish and eels from the hardware. A turbine rotor is usually the part of a hydropower system most susceptible to mechanical damage. Turbines of different types and scales will have different maximum bar spacings to limit the size of debris that passes through the rotor. The larger the rotor, the larger the pieces of debris that can be tolerated. Waterwheels and Archimedean screw turbines can pass much larger pieces of debris than Kaplan or Crossflow turbines. Turbines with small jets such as Pelton or Turgo turbines often have a maximum bar spacing of a few millimetres to prevent jet blockages.

Fish and eels are screened to reduce the risk of injuries and mortalities caused by the hydro system hardware and also to avoid migratory fish or eels from being attracted to dead end channels where they may get stranded or become an easy target for predators. Injuries can be sustained by physical contact with any fixed or moving parts, by hydraulic shear stress or by sudden pressure change, as found across certain types of rotor.

Based on the likelihood of causing injuries to fish, turbines of different types and sizes have different Environment Agency recommendations for maximum bar spacing. In addition there are regulations which stipulate maximum bar spacings for the protection of elvers and eels.

Intake screens are often angled across the flow at an acute angle to the centreline of the watercourse. This increases the screen area as well as providing passive guidance for fish to the downstream end of the screen where a bywash or fishpass is often located.

The minimum screen area is determined by the design flow rate and the stipulated maximum flow velocity. The maximum flow velocity is usually set at 0.25 m/s, which is deemed to allow the majority of fish to be capable of swimming away from the screen, against the intake flow. A lower intake velocity can sometimes be stipulated if elvers are present in the watercourse. Intake screens must be oversized to allow for a certain proportion of blockage due to debris. The blockage reduces the screen area and increases the flow velocity. The allowance for blockage is higher for manually cleaned screens than for automatically cleaned screens.

Intake screens are usually made up of vertical flat steel bars, orientated in line with the flow and inclined to aid cleaning. The bars are fabricated into manageable sections and mounted into either a steel frame or directly into a concrete intake chamber. Stop log board slots or sluice gates are usually installed upstream of the intake screen to allow for maintenance.

Intake Screen Cleaning

Waterborne debris can float on the surface of the water or be suspended beneath it. The debris is carried towards an intake screen by the flow of water passing through the screen. Debris which cannot pass through the screen builds up on the upstream side. This reduces the capacity of the screen and increases the head loss across the screen. These effects both result in a reduction of power output at the turbine.

At hydropower sites with low flow rates or particularly low volumes of debris the intake screen can be cleaned manually. The screen can be cleaned by dragging a rake up the inclined screen and lifting the debris into a debris trough located behind the screen. A flushing channel is often provided to return the debris to the watercourse downstream of the intake. A manually operated sluice is often used to allow water to flow along the flushing channel to carry the debris.

An intake screen will usually require daily cleaning throughout the majority of the year and more frequent cleaning during autumn when debris volumes are higher. Manual cleaning of an intake screen takes roughly ten minutes. Other maintenance will be limited to minor repairs and the screen should last for at least 25 years. Figure 8 shows a typical intake screen.

Figure 8 – Manually cleaned intake screen

Electrics and Grid Connection

Generator

Small scale grid connected hydropower systems usually use an asynchronous induction generator. The generator is grid excited and cannot operate without the grid being energised. It therefore cannot operate as a stand-alone system in the event of grid failure. The generator must be installed at a location where it is very unlikely to flood, either above flood level or inside a sealed chamber.

Induction generators require very little maintenance. See Appendix 6 for detailed VLH maintenance information. Corrosion protection will require design consideration, and have maintenance implications.

Control System

The control system manages the turbine and generator so that they operate within the limits specified by the environmental and technical design. At each site, the system is tailored to maximise energy capture whilst maintaining water level and reserve flow requirements. The control system also protects mechanical and electrical components from overload.

The control system adjusts the flow control component of the system to vary the flow rate through the turbine. This is done based on the upstream water level. A falling upstream water level will cause the flow through the turbine to be reduced and vice versa. The flow control component can be a sluice gate, a valve, or adjustable guide vanes. An electric or hydraulic actuator is used to vary the degree of opening.

Other than regular checking for normal operation, the control system should have an annual check over to ensure correct operation. The control system can be expected to last around 25 years.

Grid Connection

The output from the generator/control system is metered at the total generation meter. This is then connected to a distribution board in the same way that a load is connected. The power fed to the distribution board will feed any local loads first. Any excess power will be exported to the grid and metered as an export on the import/export meter. If there is insufficient power from the generator to meet local loads, power will be imported from the grid and metered as an import on the import/export meter. Figure shows a schematic of a typical grid connection arrangement.

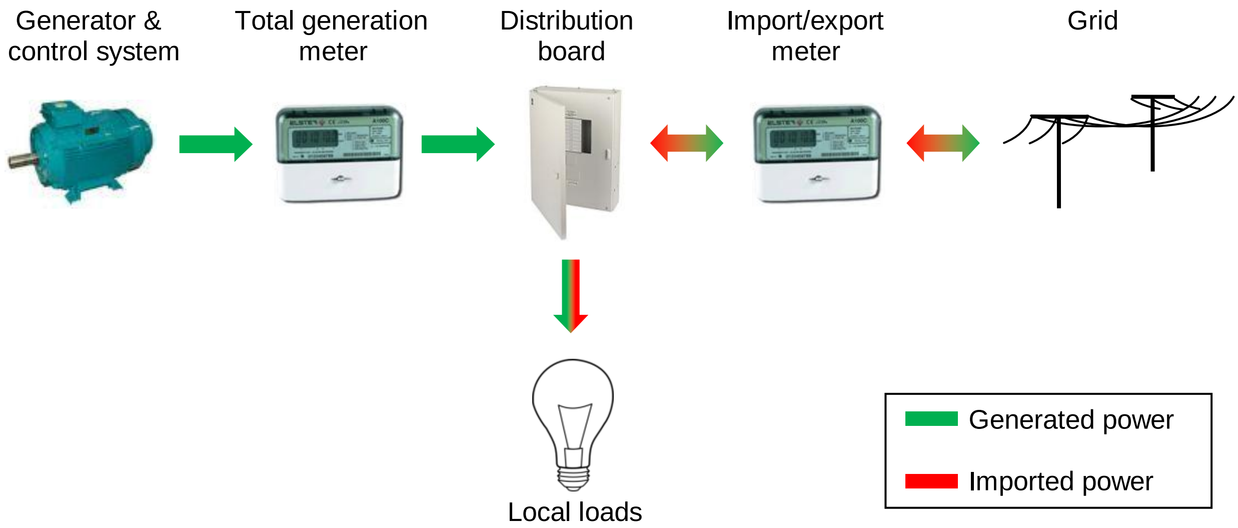


Figure 9 - Grid connection schematic

Included in the control system is a protection relay designed to meet grid connection recommendations. Larger generators fall under ER G59 which relates to the connection of generating plant to distribution systems belonging to Distribution Network Operators (DNOs). The recommendations are designed to maintain the security, quality and safety of distribution systems.

Connection of generators falling under ER G59 requires an application to be made to the DNO before installation. An operational test, witnessed by a representative of the DNO is usually required at commissioning. The electrical system should be periodically tested in accordance with standard electrical installation practice.

Power Output and Energy Capture

The flow, head and operating efficiencies have been used to estimate the power output, abstraction volumes and energy capture of the system. These are given in Table 4 below. Also shown is the mass of carbon dioxide saved by the use of a renewable energy source and the number of homes whose electrical demand could be met by the system.

Site Parameters - Fixed			
Marina Operational Window	2.0		*hours*
Mean Flow (Q_{mean})	6.93		m^3s^{-1}
Gross Head at System Rated Flows	Max	Min	*m*
	3.73	1.47	
System Parameters - Variable			
Turbine Type	VLH GC-3150-4.0		
Turbine Rated Flow	Max	Min	m^3s^{-1}
	12.3	4.8	
Efficiency (Water to wire)	70%		
Rated Electrical Power Output	100		*kW*
Annual System Downtime	7		*days*
Maximum Daily runtime	8		*hours*
Minimum Daily runtime	3.42		*hours*
Annual Abstraction	48,863,730		m^3
Energy Capture			
Annual Energy Capture	226919		*kWh/year*
CO_{2e} emissions savings	113460		*kg CO_{2e}*/year
UK homes powered	52		*homes*

Table 4 – Power output and energy capture

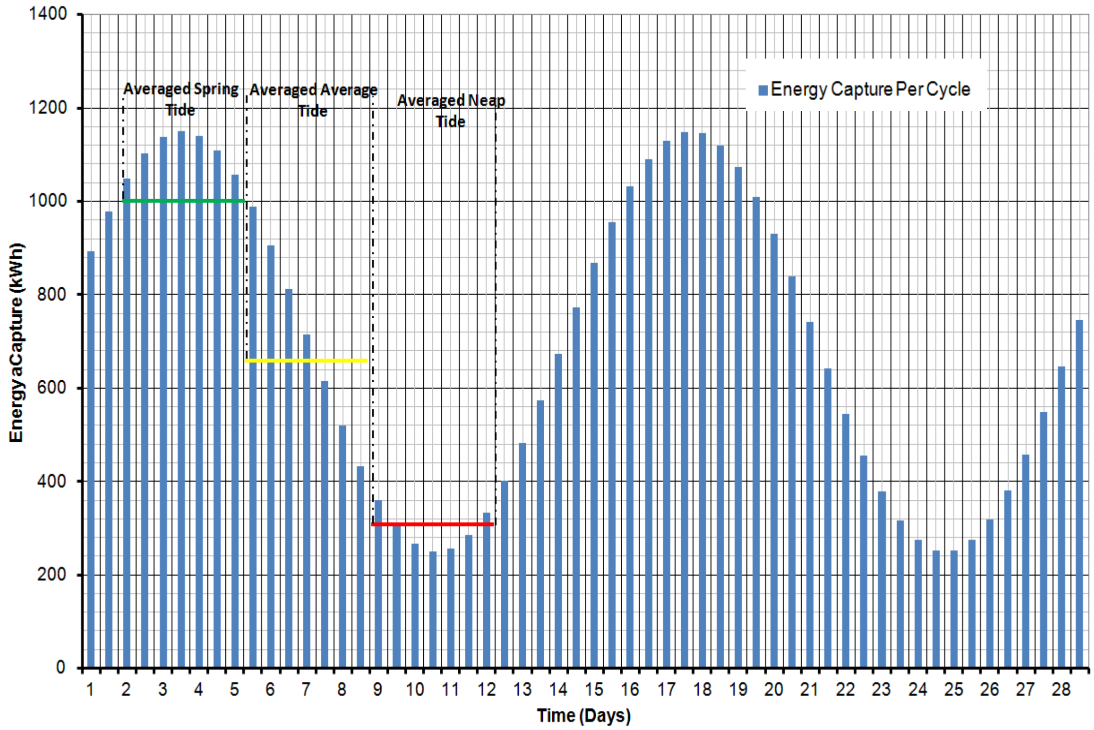


Figure 10 - Indicative forecast of monthly energy capture

Cost Estimates, Benefits and Return

Cost Estimates

Capital Cost Estimates

The costs below are budgetary. Accurate costs can be established once a design is developed.

ITEM	
Licensing, Network connection permission and Planning	£ 20,390
Detailed Design	£ 19,000
Civil Works for Intake, Penstock, Turbine and Discharge	£ 280,647
Grid Connection & Electrics	£ 12,167
Hardware	£ 582,426
Hardware Installation	£ 12,086
Project Management & Commissioning	£ 31,937
TOTAL	£ 958,652

Table 5 - Estimated capital cost

Ongoing Cost Estimates

The maintenance cost below allows for periodical servicing with a system overhaul every four years to reapply anti fowling protection, and a full service every 15 years. The replacement of parts as predicted for a 40 year lifetime.

ITEM	
Maintenance (labour)	£ 2,269
Maintenance (materials/plant)	£ 3705
Insurance	£ 4,060
Business Rates	£ 4,620
Metering	£ 408
Communications	£ 60
TOTAL/year	£ 15,116

Table 6 – Estimated annual ongoing costs

Benefits and Return

Annual Revenue

The annual revenue is based on the income from the Feed in Tariff (FiT) and the value of the electricity used to displace on-site consumption. It has been assumed that 100% of the electricity generated will be used on-site. The cost estimate for electricity in 2016 is 10.92 p/kWh. A tariff estimate of 15.78 p/kWh has been used to account for the decrease anticipated at time of Pre-Accreditation in 2015. Further details can be found in the Selling Generated Electricity section.

The FiT rate assumes that a pre-accreditation (see Project Plan) was submitted after March 2015 and the Offset figure that 100% off the power would be used for the Inner Marina and other onsite meters.

Feed in Tariff	Export	Offset	Total Revenue
£ 35,799	£ -	£ 24,780	£ 60,578

Table 7 - Annual revenue

Simple Payback, Net Present Value and Return

The Simple Payback, Net Present Value (NPV) and Internal Rate of Return (IRR) of the system are given below, assuming a 25 year lifetime. Ongoing costs are included in the figures.

Simple payback	NPV at 0 % discount rate	IRR
	(25 years of operation)	
27 years	-£ 1,081	negative

Table 8 - Simple payback

The estimated annual revenue from the system is plotted in Figure 11. Also shown is the present value of projected cash flows. The capital cost can be clearly seen at the start of the project. The drop in revenue after twenty years of operation is due to the termination of the Feed in Tariff.

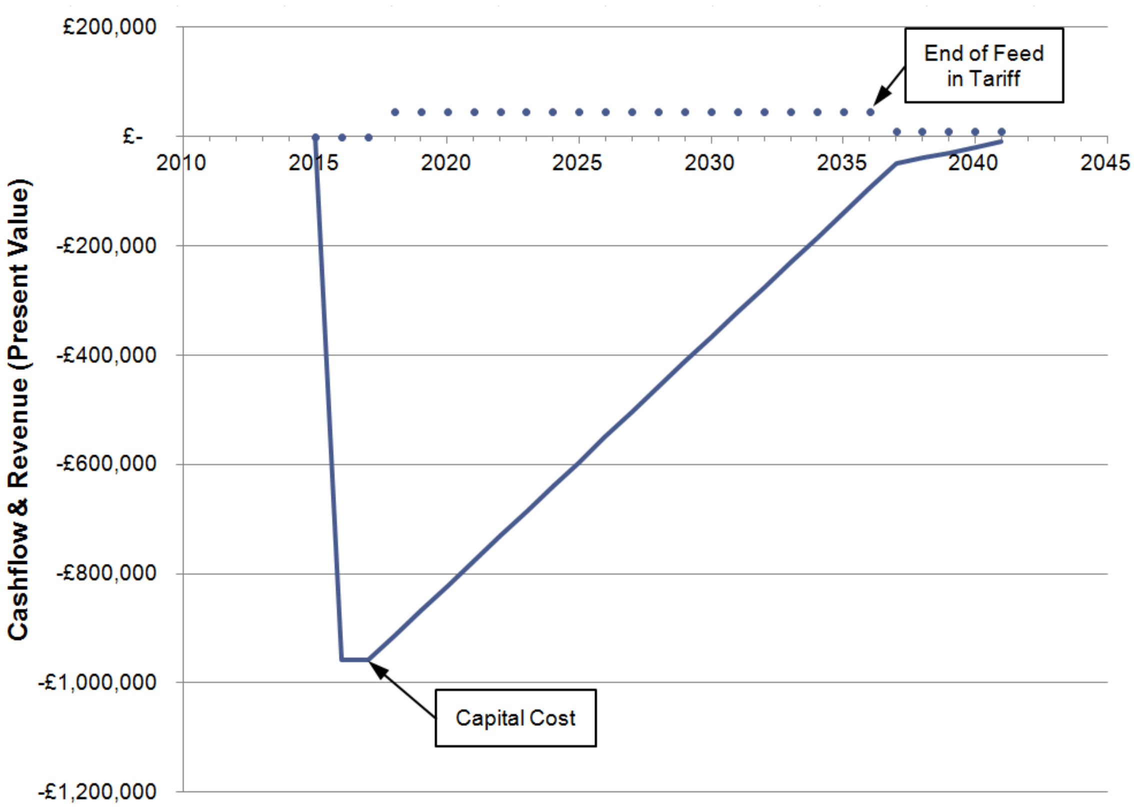


Figure 11 - Projected cash flow & revenue

Recommendations & Next Steps

Reflecting on the purpose of the scheme, the site provides a possible opportunity to develop a pilot hydropower scheme. With an estimated installed capital cost of £958,652 and annual running costs of £15,116, the internal rate of return would be negative, resulting in a net present value of -£1,081.

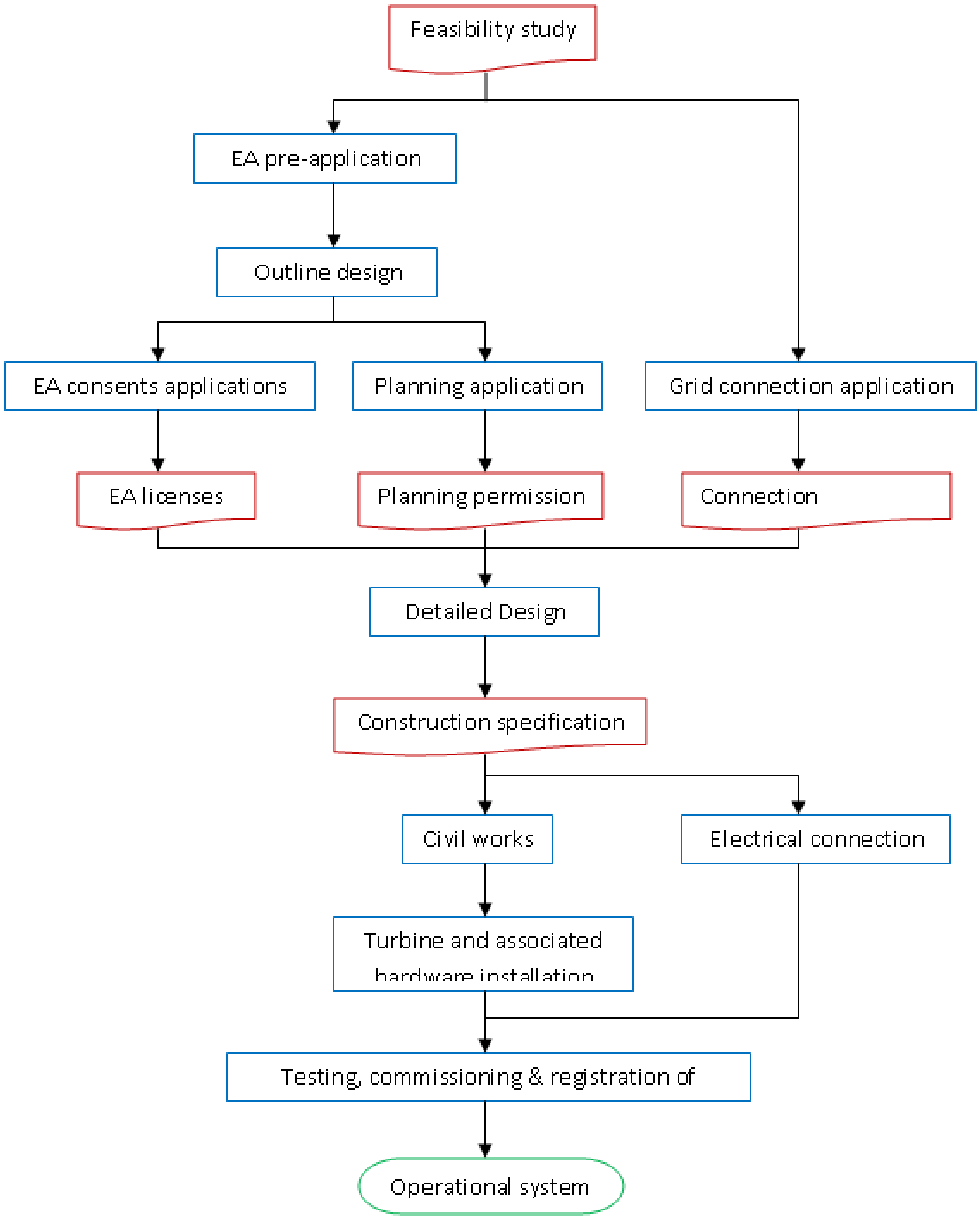
The proposed installation involves an oversized turbine, which is estimated to be over half the project cost. The installation involves preparing two of the existing sluice tunnels, cast in-situ concrete structures and significant temporary works. Given the pioneering nature of the scheme, early supplier/contractor involvement is advised as their input will significantly affect the design and improve cost estimates, as well as mitigating possible delays in the project.

The next step would be to provide an overview of the project to both Natural England and English Heritage to give them an idea of the scheme to be installed in advance of formal applications. This gives these agencies the opportunity to provide feedback on changes that may need to occur in relation to the scheme, and any licences required. After formal applications have been approved, the detailed design of the scheme can take place, leading to the installation of the scheme.

This type of project has been given a timescale of two years until completion following decreases in the Feed-in-Tariff. However, this time scale is subject to the associated project risks outlined below.

Project Plan

The flowchart below outlines the major stages involved in a hydropower project, from feasibility right through to completion.



Project Risks

The information used to decide whether to proceed with a project is based upon estimated costs and assumptions about future conditions that may affect the project's design, construction and completion. The identification and assessment of risks is valuable at every stage throughout the project. The risks detailed below have been included as they would affect the progress, cost and value of the project.

Consenting & Design Stage

The Environment Agency licenses can be refused or granted unfavourably with regards to the operation of the hydropower scheme, making the scheme uneconomical to run. This is a rare occurrence and a satisfactory agreement can usually be made during the licensing process. If the licensing decision is unsatisfactory, an appeal can be placed with the Secretary of State, adding time and cost to the project.

Grid connection costs can be a considerable proportion of the capital cost and will largely depend on the infrastructure of the local network and its characteristics. We have obtained a budgetary connection quote from the DNO and connection costs are unlikely to change beyond this, however there is no guarantee that the local network will not be altered or the generation capacity used up until the connection is finalised with the Distribution Network Operator.

Planning consent is usually required for a hydropower system. It is usually straightforward to obtain once EA licenses are approved and assuming that any construction works are sympathetic to the environment.

The design of a system is critical in both reducing construction and maintenance costs and achieving the required system performance and lifetime. A poorly designed system can easily cost more and generate less revenue than predicted.

Construction

Ground investigations can help the designer and contractor choose the most appropriate method of construction but cannot fully avoid adverse ground conditions that may lead to additional work and delays during the construction phase. Weather conditions will affect the construction programme, especially with works adjacent to a watercourse where water levels may rise higher than predicted, delaying works and adding additional dewatering and repair work. In addition, the quality and delivery time of construction materials and hardware can also affect the programme.

Careful planning needs to be carried out to avoid any delay caused by disturbance to the public, particularly where the site has a public interface. Any time delays caused by the above or other external factors can lead to further delays if construction windows set in place by environmental constraints are consequently overrun.

Programming of the work needs to be prepared with reasonable allowance of the above risks. Environmental constraints need to be detailed and included in the programme together with reasonable contingency provision for unforeseen over-runs to all aspects of the work, based upon the collective experience of the designer, the contractor and the ground investigator.

Exceptional adverse weather and unforeseen physical obstructions, both natural and artificial, remain as the main risks which will affect delivery time and out-turn costs. All other delays and costs need to be allowed for by the contractor.

The terms of agreement or contract used need to be appropriate to the work in order to allocate risks to those best equipped to manage them. Also to be included are all the requirements of the work including construction periods, completion dates, quality and out-turn costs.

Post Installation

Usually, environmental licenses are time limited, usually to 12 years, with a presumption of renewal upon expiry. After expiry, new licenses must be applied for which must meet the criteria of any existing and new legislation.

The Feed in Tariff is a Statutory Instrument, and it can be changed or annulled by Parliament. Payments made through the Feed in Tariff scheme can also be delayed if there are insufficient funds due to late payments by suppliers to the fund.

Energy capture is dependent of the tide range of each tidal cycle and the volume stored within the Inner Marina, as such the energy capture can be predicted years in advance as the area of the Inner Marina will remain constant and tidal models provide accurate data for tidal ranges. Unpredictable variables which will affect the tidal range a particular cycle such as a storm surge brought about by various meteorological effects; however this will produce only small changes in a tide range and should not be prevalent for a significant number of tidal cycles.

Revenue from the system will vary with changes in the price paid for exported electricity and any interruptions to generation. This could be caused by legal matters, legislative changes, mechanical or electrical failure, grid availability or retraction of regulatory permissions.

Selling Generated Electricity

The Feed in Tariff (FiT) was introduced by the UK government in April 2010 to incentivise the installation of renewable energy for the generation of electricity. It applies to generators up to a capacity of 5 MW. There are two components under the FiT; the generation tariff and the export tariff. The generation tariff is technology and capacity dependent whereas the export tariff is fixed at a nominal rate for all installations.

The generation tariff is payable on all energy generated by the hydropower system. A meter is installed at the output from the system to measure this. Energy generated will first feed any local loads with the excess being exported. The export tariff is payable only on the energy exported.

Installations must be registered for the FiT in order to claim it. In order to get registered the installation must be approved through the ROO-FiT process.

Both components of the FiT can be claimed through one of the FiT Licensees, who are also electricity suppliers. The FiT Licensee will check that the installation is ROO-FiT accredited and will register the installation with Ofgem. The Licensee will then make payments to the generator based on meter readings. Figure 1 provides a graphical representation of the registration process.

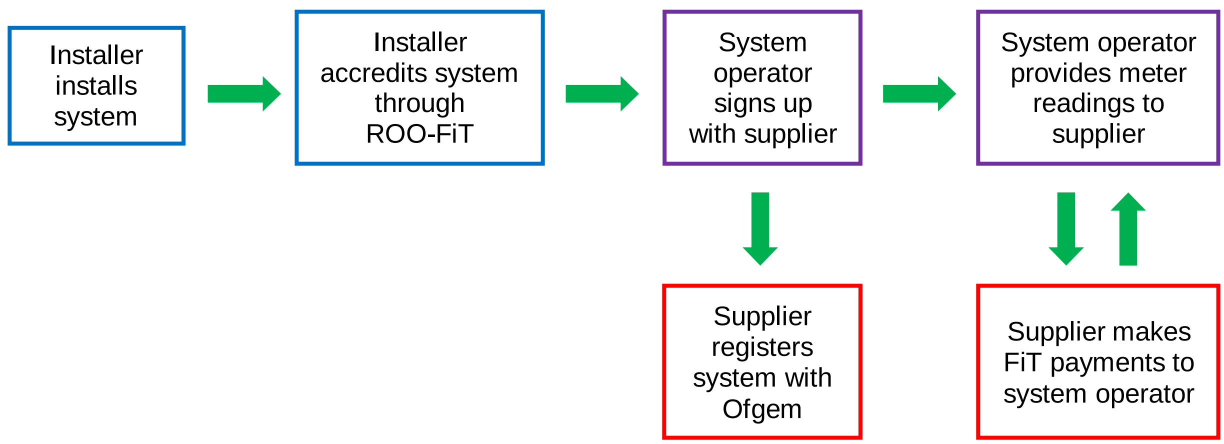


Figure 12 - Feed in Tariff registration process

Generators with a capacity of 30 kW or greater must have an export meter installed to claim the export tariff. Below 30 kW an export meter is optional. At present, suppliers will assume that hydropower systems below 30 kW will export 75 % of the total energy generated.

Large hydropower systems can benefit from a higher export rate by opting out of the FiT export tariff and either sell at a varying rate or by entering a Power Purchase Agreement with a supplier. It is uneconomical to do this for small systems due to the additional administration expense.

The FiT will be paid on generation and export for a period of twenty years from the year of commissioning. The tariff rates are index linked to the Retail Price Index and will be adjusted every year. The generation tariff is outside the scope of VAT. VAT registered generators should request their export payments to be paid plus VAT and will be required to provide a VAT receipt to the supplier.

The Climate Change Levy (CCL) was introduced in 2001 by the Government. It is a charge on the supply of electricity for non-domestic uses. Electricity generated from renewable sources is exempt from the charge. Ofgem accredited generators of renewable energy will be issued Levy Exemption Certificates by Ofgem for every megawatt hour of electricity produced. These can be sold to suppliers who allocate them against the supply of electricity to non-domestic customers. The supplier can then claim the CCL exemption.

Appendix 1 Site Photos

Figure A1.2 – View (east) of Inner Marina inlet to Sluice Tunnel #3 (Flap gate closed)

Figure A1.3 – View (north) of Sluice Tunnel #1 blocked by bulk head (top) and timber stop logs (bottom. Viewed at low tide.

Figure A1.4 – View (north) of Outer Harbour entrances to Sluice Tunnel 1 and 2 (at low tide)

Figure A1.6 – View (southeast) of groins extending from Sluice Tunnels 1-2 into the Outer Harbour (low tide)

Figure A1.7 – View (east) of Boat Park Substation

Figure A1.8 – View (west) of East Crosswall Substation

Figure A1.9 – View (south) of traversing cable entering culvert

Figure A1.10 – View (east) of access to Sluice 1 and 2 from West Pier via Military Road.

Figure A1.11 – View (northeast) of access to Outlet of Sluice Tunnel 1 and 2(High Tide)

Appendix 2 Existing drawings

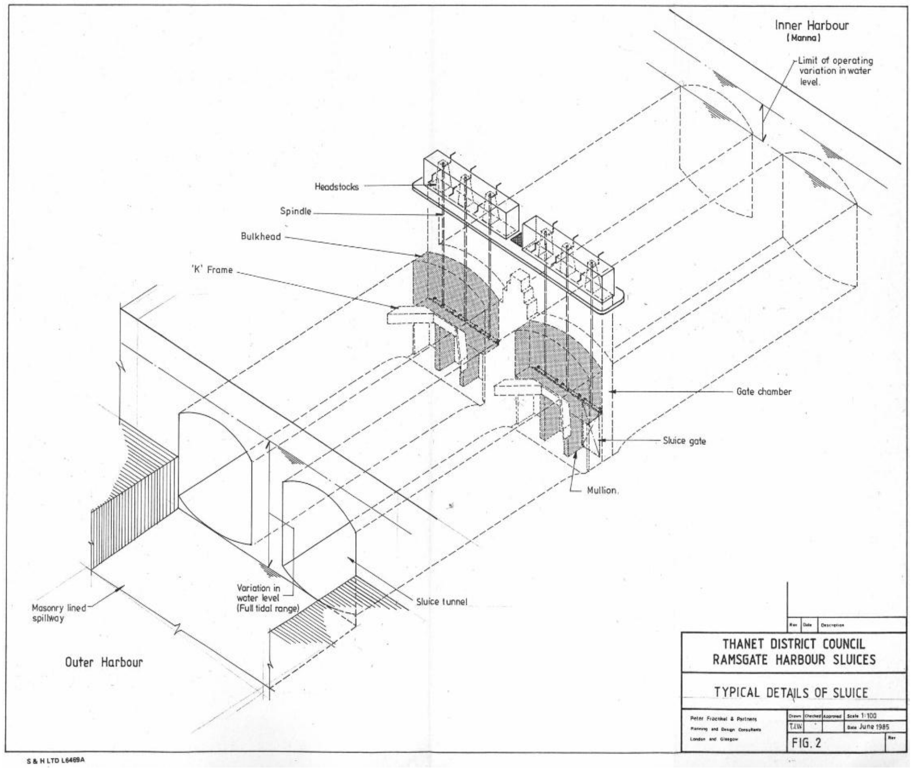


Figure A2.1 Typical Sluice Tunnel configuration, courtesy of the Peter Fraenkel & Partners report 1985.

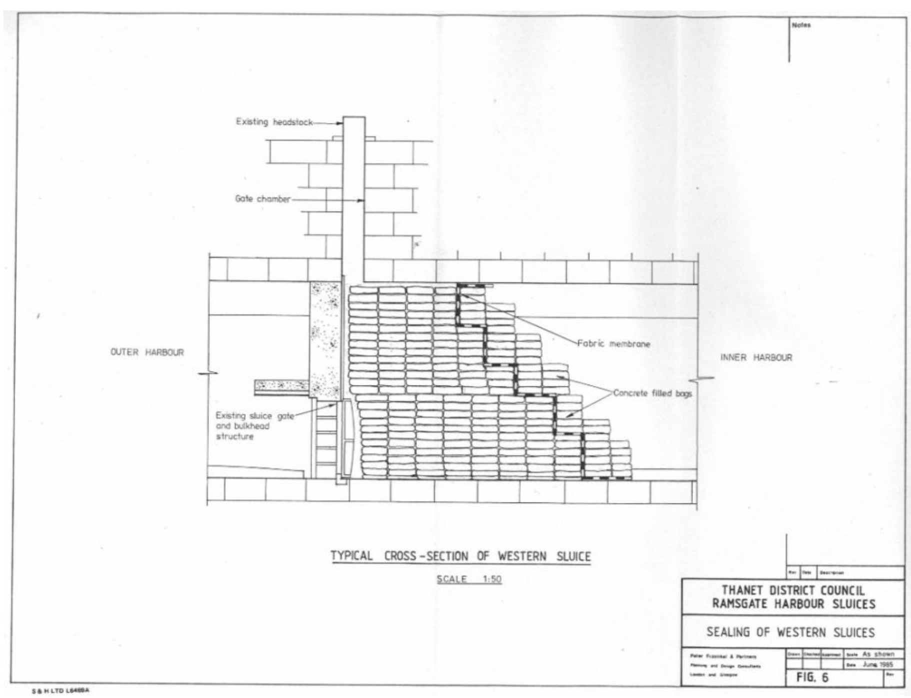


Figure A2.2 Detailed capping technique used block Sluice Tunnel 1 and 2

Appendix 3 Surveyed Levels

Number	Location	LVL	LVL
		(mAOD)	(mCD)
1	BM (TR 3819 6444) NW face BLDG SW Side W Pier	6.52	9.1
2	TBM GL top of stairs harbour wall	5.76	8.34
3	GL on Crosswall above sluice tunnel #1	5.50	8.08
4	Landing midway down stairs	2.57	5.15
5	Bottom Step	-1.46	1.12
6	Bottom of Tunnel (Add 1.02 m for silt)	-2.18	0.40
7	WL Low Tide 8.00am	-2.18	0.40
8	Step (Swing PL)	0.87	3.45
9	TBM	5.77	8.35
10	BM	6.52	9.10
11	Top of Slab above sluice one. Marina Side.	5.40	7.98
12	WL in Marina 9.00am.	1.10	3.68
13	Marina WL 12.48am	2.90	5.48

Table A3.1 – Surveyed levels

For Ramsgate harbour, all Chart datum levels are 2.58 m above Ordinance datum Newlyn.

Number	Install Location	Head
		(m)
7 to 13	Difference between Outer Harbour water level at 08h00 to Marina water level at 13h00	5.08
7 to 12	Difference between Outer Harbour water level at 08h00 to Marina WL at 09h00	3.28

Table A3.2 – Head Measurements

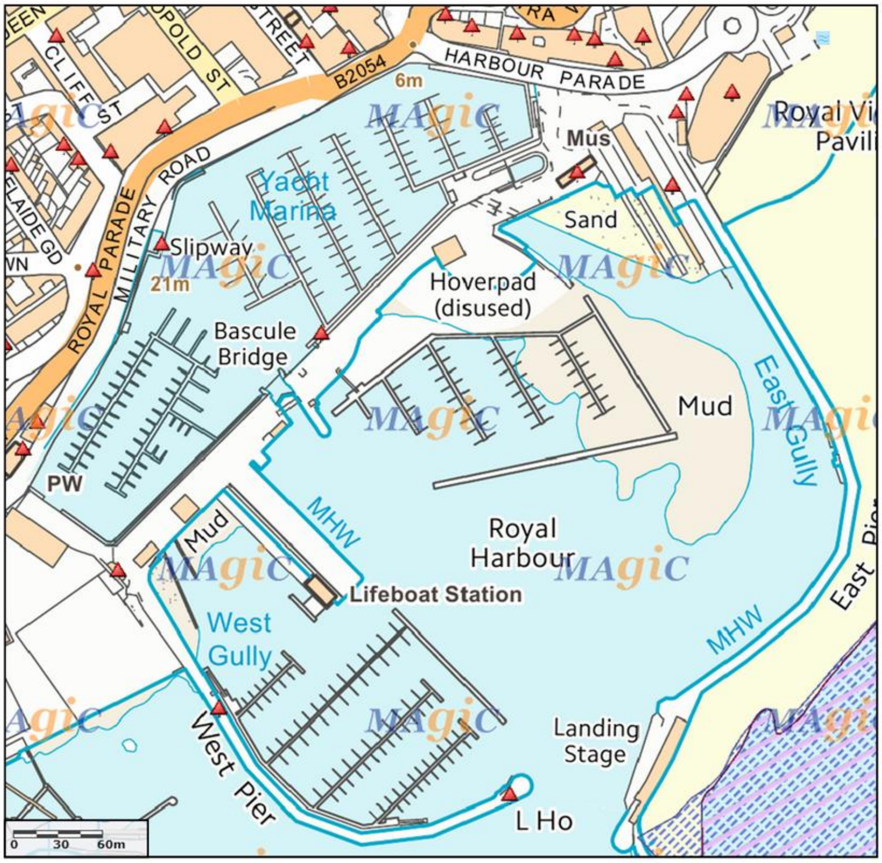
Glossary Of Terms			
OBM	Ordnance Survey bench mark	BL	Bed level
TBM	Temporary bench mark	GL	Ground level
CP	Change point	IL	Invert level
LVL	Level	OL	Outfall level
WL	Water level	THL	Threshold level

Table A3.3 – Survey Abbreviations

Level	LVL mCD	LVL mODN
Crosswall Crest	8.08	5.5
Mean High Water Spring (MHWS)	5.2	2.62
Minimum Marian Level (MML)	3	0.42
Ordinance Datum (OD)	2.58	0.00
Mean Low Water Spring (MLWS)	0.6	-1.98

Table A3.4 – Survey levels and Tidal Levels

Appendix 4 Environmental Designations



Listed Building (England)

Inshore Special Area of Conservation with Marine Components (GB)

Special Areas of Conservation (England)

Appendix 5 Geological Information

1:50 000 scale geology

Superficial deposits

- TIDAL FLAT DEPOSITS - CLAY AND SILT
- BEACH AND TIDAL FLAT DEPOSITS (UNDIFFERENTIATED) - SAND AND GRAVEL [UNLITHIFIED DEPOSITS CODING SCHE
- BEACH AND TIDAL FLAT DEPOSITS (UNDIFFERENTIATED) - SAND, SILT AND CLAY [UNLITHIFIED DEPOSITS CODING
- HEAD, 1 - CLAY AND SILT
- HEAD, 2 - CLAY AND SILT
- STORM BEACH DEPOSITS - SAND AND GRAVEL

Bedrock geology

- THANET FORMATION - SAND, SILT AND CLAY

Appendix 6 MJ2 VLH Maintenance Summary

Maintenance Design and Manufacturing Criteria of VLH

1. Basic parameters governing the conception of the VLH turbine:
The level of admissible stresses, the bearing specific pressures are the same as for a classic turbine, exception for the new components detailed in point 3. Therefore the VLH will have a comparable expected duration life compared to a classic turbine, of course if regular maintenance is performed in due time.

2. The maintenance is basically the following:
Each week:
Shaft seal lubrication (in operation): it is done manually in Millau. It could be done automatically for future sites by means such as electrical pump
Cost: grease consumption, a few kg per year.

Each year:
Shaft bearing re lubrication (in operation) and general inspection (unit out of water)
Cost: consumption, a few kg of grease per year
Manpower: 4 hours
Change of Frequency converter air filters.
Manpower: 4 hours.

Each three years:
Unit out of water
Change the rotating seal
Cost: Part 1500 Euros
Manpower 3 hours
Control of the trash rake cleaner, change of worn elements, cost and extend of new pieces depends on the number of cycles realised by the TR Cleaner and on the VLH size.
Manpower 5 hours.

Each four years:
General visual exterior inspection, change the anodes (if any) and painting repairs if necessary (unit out of water)
Cost: Painting, anodes 2500 to 3500 Euros,
Manpower 16 hours

Each ten to twelve years:
Machine dismantled and extracted from site location.
General overhaul including changing of the roller bearings, shaft seal, servomotors seals, blades bearings. To be done in a dedicated workshop. Cubicles revision
Cost: Parts: 4-5 % of the total electromechanical package
Manpower: 3 weeks, two persons 240 hours.
Cost for extracting the unit and transportation in workshop not included.

3. Basic components of the VLH:
Shaft:
The design is based on a stationary shaft on which the runner is rotating. The shaft is not exposed to fatigue. The shaft line comprises one guide roller bearing and acombined thrust and guide roller bearing. The upper guide bearing is grease lubricated while the thrust bearing and guide bearing is oil lubricated, with a duration life expectation calculated for more than 100.000 hours (SKF new method). The shaft seal is made with a pack of four lip seals running on a ceramic coated sleeve. Due to the very low rotation velocity, this seal will have a much longer duration life than on conventional unit.

Runner:
The runner hub and top covers are made of casted iron, including blades bearing housings and shaft roller bearing housings. The runner supports also internally the generator rotor and the magnets magnetic sheets. The transmission of the turbine torque is done directly through the runner and generator hub.

Blades:
The shape is specially designed to be able to close fully on closing contact. They are moulded in casted aluminium for the lower heads and in casted iron above 2,5 m head. This design is different compared to a classic one. The blade surface is painted with epoxy.

Blades shafts:
They are rotating on a self lubricating sleeve inside the runner hub and on a ball bearing on the runner periphery. This design is to minimize frictions and to limit governing work. The ball bearing is lubricated for life (grease could be changed at the general overhaul). The blade shaft seals are of the same technology as for the main shaft seal. Design is equal or better than those of conventional turbines.

Blades mechanism:
Made with levers and regulating ring. The junction between levers and regulating ring is done by self lubrication sleeves and ball bearing. Each blade is equipped with a spring to limit the closing forces if debris are blocked between to blades. The design is equal or better than conventional turbines.

Generator:
Special concept with an internal stator built with independent sectors connected on a circular bus. Isolation class F. Cooling class B. Possibility to change the sectors individually. The rotor is integrated in the runner band and the excitation is done with neodymium permanent magnets.
Cables are going through the centre of the main shaft. Stainless steel cables glands are adjustable and located externally.
The runner hub is pressurized by air, approx 2 m above existing water pressure (Air unit supply including compressor and air dryer)

Distributor:
Made with welded steel. Protection is performed by painting (zinc primer+ final epoxy). In option, magnesium service anodes are installed on the distributor structure to prevent electrolytic corrosion.

Frequency converter:
Supplied by ABB in the ACS800-77 range. The frequency converter plays also the role of a frequency increaser. IGBT's (Insulated Gate Bipolar Transistor) could be changed easily in a few hours. Spare parts are not expensive (typically 1000 Euros per IGBT). The frequency converter includes also a circuit breaker to disconnect the inverter from the grid and the generator from the frequency converter. Note that, with the frequency converter, the starting and stopping sequences are done with a minimum of amps when coupling to the grid (except in case of grid failure, in this case it is comparable to a classic situation).
The frequency converter is the key element that allows the VLH to work with a variable speed and therefore optimises production by adapting automatically the turbine speed to the existing net head. Thanks to this feature a VLH can maintain nominal efficiency down to 40% of the nominal head.

Command & Control:
It is based on a classic PLC which drives the frequency converter and the main low voltage cubicle. Men Machine interface is carried out with a touch screen. The system can be accessed through internet.

Oil pressure unit:
It is a classic HPU with gear oil pump, tank and accessories. The working pressure for the blades servomotors is 70-80 bars in order to increase the rotating seal life.

4. Sand abrasion and sediment transport
Due to the relatively low water velocity in the water passages, the VLH turbine is less sensible to abrasion than a conventional unit (ratio of velocities is in the range of 4 to 5). So the general structure will not suffer too much from a certain amount of sand in the water compared with a classic turbine. Due to the very thick blade shape, the blade body is hollow but closed at each extremity.
For rivers with heavy sediment transport, MJ2 has designed special bottom gates, with hydraulic control; located in the lower part of the supporting structure. These gates may be open in flood conditions thus allowing an important part of the flow and the main sediments to be transferred downstream of the VLh avoiding the runner and the blades.

5. Norms
Design of the mechanical parts is done according to our internal quality book. Safety coefficients and durability objectives are set according the state of the art and, generally, they are similar to those applied among turbine manufacturers.
The VLH is a standard machine, calculation notes are not published for intellectual property protection.

MJ2 Technologies S.A.R.L. Conception et Fabrication de Turbines Hydroélectriques
Tel : +33 (0)565599946

October **2012**