WG197 SMALL HYDROPOWER IN WATERWAYS BEST PRACTICE

WG197

Introduction

Many inland navigations have the basic ingredients for a hydro power plant in existing infrastructure. A number of inland navigation owners have taken advantage of their infrastructure to build hydro plants and to generate extra revenue or reduce operational costs. Whenever the infrastructure around rivers or canals is modified, improved or even just maintained, many factors beyond simply doing the work come into play. Some of these can add considerably to the cost or even stop a project before it starts.

This paper briefly describes the issues and then looks at how these can be addressed with direct reference to plants that have been constructed on inland navigations. Generalised hydro plants are not considered, only those built specifically on inland navigations are included.

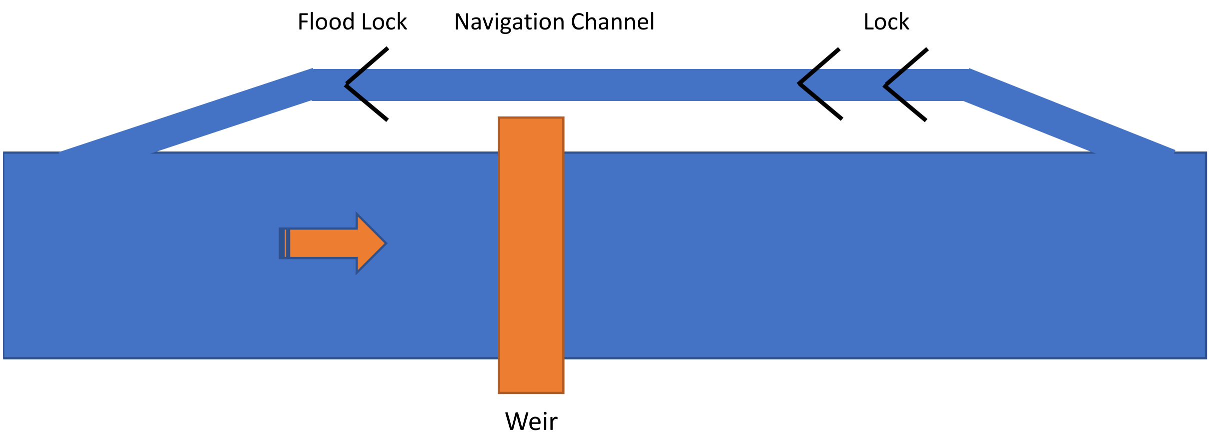
The ways in which these owners and operators have dealt with the issues provide a useful insight into what can be achieved.

Hydro-power in inland navigations

A typical arrangement is shown below with a navigation channel around a weir. The navigation might be a river navigation or a completely man-made canal. The flows might be less in the case of a canal, but they can still be significant and still capable of delivering meaningful energy outputs.

All the basic ingredients for a hydro power station are present:

- Impounded water
- A difference in levels – a head
- A flow of water



The owners, managers and operators of inland navigations all know the difference in levels and have a historical record of the variation of flow over time at the at each weir and lock location. Whilst the water has other uses, particularly for navigation and compensation flows, any surplus can be put to good use generating power.

The technology of hydro power is widely understood and generally mature, but manufacturers have recently been developing turbines to operate at lower heads, sometimes combined with variable speed generators, to exploit more marginal heads and flows.

The working group has restricted itself to a head range of 1.5 m to 15 m and a power range from 100 kW to 10 MW as might be encountered on inland navigations.

Issues for development

Navigation

The prime function of inland navigations is, of course, navigation. The development of a hydro plant and the se of water for generation needs to be done in such a way that navigation water levels and water supply are not affected. Priority is always given to navigation water supply and level control for navigation.

Of the two main water requirements for navigation, level control can be problematic when a significant portion of the flow in the waterway is being diverted through the turbines. When changes of flow through the turbines occur quickly, the changes to level can go beyond the navigation limits.

During starting of the turbines, the flow change is gradual and regulated by the control system specifically not to affect the navigation levels. The same can be applied to a controlled stop. However, when an emergency stop is required, perhaps because of an external influence, the turbine flow will be stopped very quickly. The water that was flowing through the turbine must go somewhere. Initially, a rise in the water level upstream of the turbine will occur. If the upstream entrance to the navigation channel is close to the weir, then the change in level can affect navigation unless corrective interventions are made. The further upstream the inlet to the navigation channel is from the weir, the less the problem becomes.

With a fixed weir, the problem can only be dealt with by modelling the flows and setting the maximum flow that the hydro plant can take to remove the possibility of affecting the navigation levels on emergency shutdown. Where the weir has an element of active control such as automatic gates or an inflatable rubber weir, then studies need to be done into the reaction of the existing control system to an emergency turbine trip – is it fast enough to keep the level change within acceptable limits – and if not, links will need to be established between the hydro turbine operating system and the weir level control system to make the system respond quicker in the event of a turbine emergency shutdown.

Flood Control

Many navigations are based around rivers and seasonal flooding has occurred over many years of operation. Ways of dealing with the floods have been developed and implemented. The addition of a hydro power station must maintain the existing flood capacity and not make the situation worse.

Where space is available, building the hydro power station off line in a new channel is the obvious solution. Where this is not possible, and the hydro power station takes up part of the existing flood conveyance channel, other ways must be found to enable to pass the flood waters.

Fish, eels and environmental considerations

The construction of a new hydro power plant on a navigable waterway, whether that is a river navigation or a man-made canal, will require consideration of the effect on fish and particularly migratory fish. Even where existing weirs have fish pass provision, when a new hydro power station is proposed, a review of the whole installation as an obstruction to the passage of fish and eels will undoubtedly be required and additional fish pass provision may be required. Where there is no existing fish pass provision, a new one will usually be required as part of any hydro power development.

Examples of best practice

Lock 51 Saint James, Meuse River, France

Like many navigation structures on the Meuse River in France, Lock 51 had a stake weir to impound the water for navigation. To renew and modernise the site, a new weir with an inflatable rubber crest was installed to actively manage the upstream water level. A new channel was cut around the weir to enable a hydro power plant and new fish pass to be built.

Active control of the navigation level upstream of the weir using the inflatable rubber crest is done separately from control of the hydro power station, but when an emergency shutdown of the turbines occurs, a connection between the two control systems ensures that the inflatable weir responds quickly enough to keep the level within the navigation limits. This is a particular challenge when the flow through the turbines represents 80% of the flow in the river which it does at certain times of the year.

Lock 51 Saint Joseph. New channel for hydro power and fish pass on the left with the existing stake weir still in place during the construction phase.

Lock 51 Stain Joseph. Fish pass of the double vertical slot type with bed substrate

There was no fish pass around the existing stake weir and the construction of the new hydro power plant required the fish pass to be built. A pool type with double vertical slot and bed substrate was chosen. This type is widely used and suitable for many fish species including benthic (bottom dwelling) fish that use the bed substrate to climb up the difference in levels.

The turbines used are “Very Low Head” turbines, a development of the Kaplan type of turbine with large slow-moving blades that are classes as being fish friendly. Only the Very Low Head turbine is considered to be fish friendly by the environmental regulators in France. Other variants of the Kaplan turbine are not considered to be fish friendly. The blades have a variable pitch which is combined with a variable speed drive to enable a wide range of flow conditions to be utilised efficiently at low heads in the range 1.5 m to 3.4 m.

Lock 57 Ham, Meuse River, France

This installation is similar to Lock 51 on the same river with the exception that the hydro plant was constructed not in a new channel, but in an existing channel that conveys flood water. The Very Low Head turbines can be lowered out of the way and protected by steel doors to allow the floods to pass over the top. A similar pool type fish pass with twin vertical slots was constructed as part of the development.

Lock 57 Ham. Inflatable rubber weir in operation. The original stake weir has been removed. It was further upstream of the new weir and its position is marked by the piers still visible.

Lock 57, Ham. Very Low Head turbines in operation. In times of flood, the turbines are lowered down and the doors are closed over the turbines to allow the full area to be used for flood discharge

Lock 1 Hastiere River Mueuse, Belgium

Downstream from Lock 57 on the same river, this time in Belgium, Lock 1 at Hastiere presents a different set of challenges. The river flows through a comparatively narrow valley with major road and railway infrastructure on one side and a relatively steep, wooded slope on the other. The weir consists of three radial gates that function both to manage navigation level and pass flood waters by rotating to be fully above the flood water level. The upstream entrance to the navigation channel is close to the weir.

There is no space on either side of the weir to construct a new channel for a hydro power plant at a reasonable cost. However, with 100 m³/s of water available for generation, the potential energy output could not be ignored. A unique solution was developed to utilise the water whilst not interfering with the flood capacity of the weir.

Six propeller turbines with fixed inlets and fixed runner blades are mounted on a steel deck that is installed downstream of one of the three weir radial gates. In operation, the gate is lifted clear to allow an uninterrupted flow into the turbines. The turbines are switched on as required to utilise the water available.

In times of flood, the whole assembly of turbines is lifted vertically upwards to clear the gate and allow it to fulfil its normal function.

The weir has an existing fish pass and no additional provision was made as a result of installing the hydro power plant. The turbines employed are classed as fish friendly in Belgium.

Lock 1 Hastiere showing six turbines mounted on a steel deck immediately in downstream of the weir gates. The vertical tower is part of the lifting equipment that lifts the deck clear of the river in times of flood.

Lock 1 Hastiere showing six turbines raised up above the water to allow unrestricted flood passage.

Knottingley and Kirkthorpe, Aire & Calder Navigation, UK

These two hydro power stations constructed around fixed weirs on the Aire & Calder Navigation in the UK. Both use double regulated Kaplan type turbines with variable inlet guide vanes and adjustable runner blades. There are two units at Kirkthorpe and a single unit at Knottingley. Fish and eel migration were major factors in the design of the two stations. Kaplan turbines are not considered to fish friendly by the UK Environment Agency. Exclusion of the fish from the turbines at the inlet was considered to be the only acceptable solution.

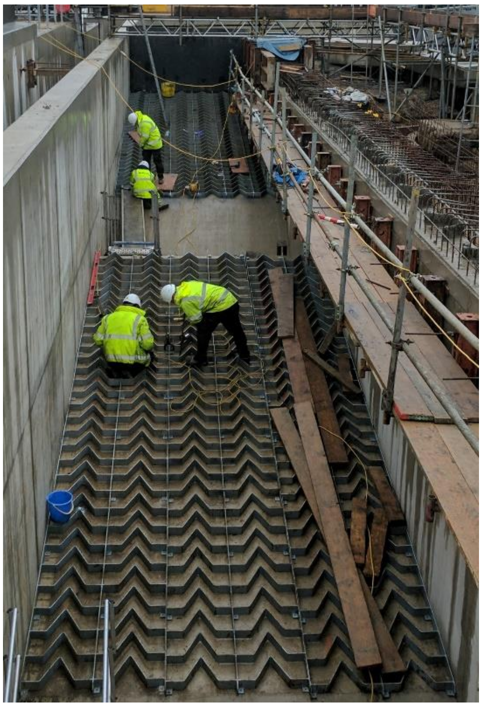
The UK Environment Agency required that the inlets be screened down to 6 mm and 9 mm at Knottingley and Kirkthorpe respectively. This has resulted in large inlet screens with horizontal bars rather than the more normal vertical screen bars that are wiped horizontally rather than being raked vertically in the traditional way. The large size was necessary to keep the head loss across the screens low. With only a few metres of head available, the head losses across the screens can reduce the energy produced significantly.

The inlets are parallel to the river and the wiper runs from the upstream end to the downstream end only. The debris is pushed towards a debris chute that takes it around the weir and into the river below the turbines.

Outlet screens are also provided to prevent upstream migrating fish from entering the turbine, but these are not raked.

Knottingley Hydro Plant, Aire & Calder Navigation. Showing the large intakes necessary and the screen wiper at the upstream end.

Both installations required new fish passes and eel passes to be constructed. The eel passes consist of pipes with an internal mat that has a constant flow of water trickling over it. The fish passes are of the Larinier super-active type with a series of steel baffles installed in a channel seen below under construction and in use – pictures from Yorkshire Hydropower.



Lock Kwaadmecheien – Ham, Albert Kanal, Belgium

Unlike the previous examples, the Albert Kanal is an entirely man-made waterway. It is fed by a number of rivers, including the Meuse/Maas River. Most of the year there is excess water but at certain times there are water shortages which can affect navigation. To overcome the shortages, pumping stations have been constructed at some of the locks using large Archimedean screw pumps with a capacity of 5 m^3/s. There are plans to equip all the locks on the canal with similar pumping stations in the next few years.

These pumps can be reversed and act as turbines to generate power when there is excess water available. The availability of water for generation is determined entirely by the needs of navigation.

The Archimedean screws whether operating as a pump or turbine are classes as fish friendly.

Conclusions

The existing infrastructure associated with inland navigations is well suited to the addition of hydro power plants of mini and small size. The resulting energy can either be used by the operator of the navigation to reduce expenditure or sold to provide additional revenue.

There are many challenges which vary from country to country but the examples presented show what can be achieved.