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Small-scale Hydro Power – a Study of the Prerequisites for Developing Mästaremåla Hydro Power Station in Lyckebyån, Blekinge

As a part of the Rural Res project a number of places have been studied regarding their suitability for small-scale hydro power. This is a study of the prerequisites in the river Lyckebyån just north of Karlskrona in the County of Blekinge.

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1 Summary

Mästaremåla hydro power station is located about 30 kilometres north of Karlskrona in Lyckebyån in the county of Blekinge the. The owner considers renovating the power station and increasing the capacity. There is a dam with several outlets, and at one of these outlets the hydro power station is located. There is a large need for renovation since for example the turbine sump and the dam leak water which reduces the possibility to produce with full power. The power station is extended for hydro power with 40 kW installed power and with the annual average production of 120 MWh. The dam's drop height is 2.4 m. With further renovation this can increase with 1 metre without large disturbances in nature and environment.

The new hydro power station will be connected to the electricity grid via an own switch tower. The electric energy produced will give the average income 0.50 Swedish kronor/kWh (0.05 euro/kWh[1]). Electric energy produced with newly established hydro power qualifies for electricity certificates which can be sold for in average 0.30 Swedish kronor/kWh (0.03 euro/kWh).

Investment calculations were made for a rebuilding with the water surface raised with 1 metre and a new adjustable Kaplan turbine (the traditional type with adjustable guide vanes and impeller blades with a 230 kW generator is installed. The calculation indicates an economic profit equivalent to 13.5% on the own capital already during the first year and on the assumption that the own input is 1,800,000 Swedish kronor (191,500 euro) and a bank loan of 4,200,000 Swedish kronor (450,000 euro) is taken. There are uncertainties about future political decisions, changes in the electricity price and the cost for building a new dam and turbine etc. Tenders for connection to the superior grid, reconstruction of dam and machine room and machine and control equipment should be requested before a final decision on investment is taken.

The first hydro power station was established during the 19th century and there are probably no disturbances in the environment.

Environmental aspects were considered from several points of view, for example supply of renewable energy and securing of minimum flow to the benefit for fishes and biotopes.

The total prerequisites were estimated as good but a relatively high investment is needed to reach a reasonably profitable production. The payoff time will be rather long but with regard to the power station's service life the risk is estimated as low and the investment in total as good.

[1] All exchange rates in the document from 25 November 2010

2 Hydro power

In a hydro power station the potential energy of the water is converted into kinetic energy when the flowing water passes the turbine's blades. The energy is produced through a generator run by the turbine.

The power generated by the throughput is directly proportional to the drop height that can be used and the water flow that can be led through the turbine. The water flow is led to the turbine house via an intake channel or intake tube. The size of the turbine as well as of the intake is determined by the water flow the power station is extended for. The turbine, or the turbines, is in a special room made of concrete, the turbine sump.

The water supply is regulated via a gate at the dam or a throttle valve in the intake tube for smaller power plants.

Start and stop of the units can be made manually or automatically with an upstream water flow meter. The modern mini hydro power stations are often controlled via float.

Depending on the drop height the hydro power plants can be equipped with different kinds of turbines. The Kaplan turbine is advantageous to use at small drop heights and large water flows. The turbine reminds on a ship propeller. The water enters radially but is directed axially and is regulated with guide vanes to get an appropriate flow direction. The blades at Kaplan turbines are usually articulated so they can be adjusted to the existing conditions. A Kaplan turbine can be used at drop heights from 2.5 to 30 metres. The units can be mounted vertically or horizontally. Most of the mini and micro power plants are equipped with a so called propeller turbine which is a kind of Kaplan turbine with fixed blades.

At larger drop heights Francis turbines or radial flow turbines are used. The water is led through adjustable vanes through a ring shaped chamber in radial direction towards the blades. This turbine can also be used at lower drop heights. Besides Kaplan and Francis turbines there are also some less common types of turbines.

The generators can produce direct or alternating current. Today there are only alternating current generators. The generator can work synchronously or asynchronously. In the beginning the power stations were built to supply electricity within a limited area. They were equipped with synchronous generators which are the only ones that can build up voltage on the grid. These generators have more expensive control equipment. Most of the new-built hydro power stations are equipped with asynchronous generators with a more simple design than the synchronous generators and are therefore cheaper. The asynchronous unit is coupled to the grid when the correct rotation speed has been achieved. When the unit has been connected the rotation speed is controlled by the grid. At power failure of the grid the unit must be stopped. The amount of energy which can be produced is mainly determined by the size of the water flow and the drop height. These physical factors put an upper limit to how much is possible to produce.

An efficient exploitation of the water flow usually requires possibilities to store in reservoirs in the water system. The need for reservoir volume is in turn determined by the size of the water flow and its variations. The occurrence of natural reservoirs in the form of lakes or marshes in a water stream facilitates an extension.

The theoretically extractable power for an entire water stream can be calculated from average values of the water stream, i.e. the average value of the water flow at the inlet/county border or outlet/county border. The total drop height is determined with the help of height values on the topographical map.

Figure 1. The mill Mästaremåla – aerial photography

Figure 2. Current hydro power station at the mill Mästaremåla in Lyckebyån

3 Economic aspects

Calculations show that it is economically profitable to renovate this hydro power station. In Sweden today the future is uncertain for the small hydro power plants (50–1500 kW). After a period of new investments and investment subsidies during the 1980s the interest for small-scale hydro power markedly decreased during the 1990s. The reason was that the subsidies were withdrawn and that the electricity prices stagnated or even went down. The deregulation of the electricity market made during the 1990s also implied that cheap electricity could be purchased from abroad, which led to difficulties to compete successfully for many of Sweden's producers of electricity. In consequence many disused small hydro power stations are not put into operation again and several in operation are shut down. The former government noticed this problem and 1 January 2003 they introduced the so-called electricity certificates.

The system with electricity certificates means that payment for electricity produced from renewable energy sources will be higher than electricity produced from other energy sources. The government's ambition with the certificates is to contribute with 10 TWh renewable electricity during 2003–2012.

The future of the electricity certificate system is uncertain at the time of writing this report. Old small-scale hydro power stations will lose their certificates after the end of 2012 if they do not increase their power. New and renovated hydro power stations will receive electricity certificates during the first 15 years after they are put into operation.

4 Methods

This prefeasibility study is based on information from hydro power mapping, GIS maps and visits at the site. Contacts have been taken with suppliers, investors and the owner to gain information and knowledge.

4.1 Evaluation of possible water stream exploitation

A good water flow is a main condition for a successful hydro power project.

Precipitation values from SMHI (Swedish Meteorogical and Hydrological Institute) for 1991–2005 were used for calculation of hydro power potential. Following data are initial values for calculation of the potential for Lyckebyån.

Precipitation the precipitation area:	659 mm/year
Evaporation in the precipitation area:	429 mm/year
Drainage per km^2/s in average:	7.3 $l/km^2/s$

The efficiency was calculated to 90% when the potential was calculated.

4.2 Calculation of energy production

Potential for the mill Mästaremåla:

Area for discharge of water:	710 km^2
Average water flow:	5 200 l/s
Exploitable water flow:	8 500 l/s
Exploitable power:	230 kW
Annual production:	925 MWh

5 Obstacles

Certain groups with special interests, for example anglers, people living nearby or authorities, could be obstacles to putting the plans into practice.

6 Connection to the power grid

Connection to superior power grid for power stations of this size is usually made to the low voltage side in a transformer owned by the electricity grid owner. Fuse protection towards the transformer will maybe be too high and it is probable that the grid owner needs to reinforce the input transformer. The cost for reinforcing the grid will be paid by the grid owner and is estimated to approximately 200,000 Swedish kronor (21,000 euro).

7 Choice of machine equipment

Due to the large variation in water flow and the fact that the hydro power station lies in a stream without possibility to store in a reservoir there is a need for some kind of adjustable turbine. To get high efficiency also when the flow is low a Kaplan turbine is preferred. This type of turbine has adjustable blades as well as guide vanes. The generator will probably be an asynchronous generator magnetized via superior grid. The cost for this kind of generator is much lower than an equivalent synchronous generator that manages to handle so-called island operation. To guarantee long-term operation the existing dam must be reinforced and the river channel cleaned. The hydro power station should be equipped with a level sensor connected to an electrical cabinet with control equipment regulating the turbine’s guide vanes and blades based on the existing conditions.

8 Investment calculation

An investment calculation showing the payback time has been made for a hydro power station with 230 kW installed power. The calculation is based on a number of assumptions and the result should therefore be seen as an indication. Before a final decision on investment is taken tenders must be requested covering the total investment with turbine equipment, electricity connection, dam, cleaning, renovation of machine room and refrigerating plant. The calculation sheet will be updated when this information is known.

The annual production is assumed to be equivalent to 4000 hours at full power. An annual production of 6000 hours at full power calculated with the flow 5 m^3/s is however more realistic.

One bank contacted (Den Danske Bank) requires an own financing of more than 30%, and the remaining part of the investment can be borrowed with an interest rate of up to Stibor (Stockholm Interbank Offered Rate) +2.5%, in our calculation 6% interest.

The running cost is indexed to an annual increase by 1% per year.

The electricity price is estimated to be 0.50 Swedish kronor/kWh (0.05 euro/kWh). The price is normally a little higher in winter and a little lower in summer.

The price of an electricity certificate is estimated to 0.30 Swedish kronor /kWh (0.03 euro/kWh). Electricity certificates can be received during the first 15 years according to current political decisions.

Payment for grid benefit paid by the owner of a superior grid is estimated to 0.07 Swedish kronor /kWh (0.03 euro/kWh). The price is higher in winter and lower in summer.

The calculation is based on current regulations.

Calculation – Mästaremåla

Kalkyl Lyckebyån - Mästaremåla 2010-08

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