MSc Program
Renewable Energy in Central and Eastern Europe

Studies to improve an existing Small Hydro Power Plant in Styria

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
o. Univ. Prof. Dr. Helmut Drobir

Dietmar Rudolf Paar
Student ID 0627530

Vienna, October 25, 2009

Affidavit

I, **DIETMAR RUDOLF PAAR**, hereby declare

1. that I am the sole author of the present Master's Thesis, "STUDIES TO IMPROVE AN EXISTING SMALL HYDRO POWER PLANT IN STYRIA", 41 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 25. 10. 2009

Signature

ABSTRACT

The potential of small hydropower in Austria is a widely underestimated resource. The potential of extension in the region of small hydro power plants up to the year 2020 is estimated for 2 TWh, there from 0,7 TWh by optimization of already existing plants.

The goal of this thesis is to show economical and technical possibilities, especially in upgrading of these already existing small hydro power plants.

The thesis presents the options of power enhancement as an example of a - since 1937 in original condition working - small hydro power plant.

Afterwards we check the results for plausibility, comparing it with the performance data of an also long existing, but already 2006 renewed small hydro power plant.

The thesis includes also information about the technical fundamentals of small hydro power plants and will be a short compendium on the area of performance enhancing of small hydro power plants.

The position of the discussed power plant is in a part of Styria where water power has been used for industrial applications for centuries. Therefore a short part of this work will show the historical dimensions.

TABLE OF CONTENT

Affidavit……………………………………………………………….…………1
Abstract…………………………………………………………………….…….2
Table of content……………………….……………….……………….………3
List of Figures…………………………………………………   ………….…4
List of Tables……………………………………………………………..………5
1 Introduction……..… ………………………………………………..………6
1.1 Motivation…………………………………………………………..…..7
1.2 Core Objective of Work…………………………………………….....7
1.3 Citation of Main Literature………………………………….………...8
1.4 Structure of Work……………………………………………….……..9
2 Background Information…………………………………………………10
2.1 Geographic Background…………………………………………………10
2.2 The Industrial History of Thörl/Styria/Austria…………………………...11
2.3 The History of Water Turbines……………………………………..…..13
2.4 Definition of Small Hydro Power Plants and the substantial Devices.14
2.5 A diversion Plant consists of…. Description……………………………15
2.6. How to calculate the capacity of a Hydro Power Plant………………..19
2.7. Performance enhancing of long existing Water Turbines…………….20
3 Description of method of approach applied……………………………23
4 Documentation of data and data collection……………………………24
4.1 Small Hydro Power Plant "Margaratentenhütte"……………………….24
4.2 Small Hydro Power Plant "Vincenzturbine"…………………………….29
5 Description of results……………………………………………………..39
References………………………………………………………………………41
Acknowledgements

List of Figures

Figure 1: “Atlas Steiermark, Wasserwirtschaft, Gewässerkartei”

Figure 2: Early industrial time, Ironworks Thörl

Figure 3: The last old hammer driven directly by water power and in use until 1921

Figure 4: Turbines’ type field of application

Figure 5: Founders board 1926

Figure 6: Historical board 1966

Figure 7: Nameplate of turbine

Figure 8: Nameplate Generator

Figure 9: “Vincenz Turbine”

Figure 10: Hydro power plant Vincenzturbine front view

Figure 11: Vincenzturbine: The weir

Figure 12: Vincenzturbine Headrace channel

Figure 13: Vincenzturbine Intake

Figure 14: Vincenzturbine Surge Tank

Figure 15: The original Label

Figure 16: Vincenzturbine: The turbine generator unit

Figure 17: Vincenzturbine: Mechanical turbine controller

Figure 18: Vincenzturbine: The original tools from 1937

Figure 19: Vincenzturbine: The electrical system

Figure 20:“Wasserschloß” Elektrizitätswerk Thörl

Figure 21: Zentrale Originalplan J.M. Voith

List of Tables

Table 1: Range of Heads

Table 2 Flow and head variation acceptance

Table 3 Maximum efficiency of modern turbine types

Table 4: Total efficiency – Calculation and increase – Margaretenhütte

Table 5: Total efficiency – Calculation and increase – Vincenzturbine

1. Introduction [1)]

Hydropower is one of the oldest renewable energy sources. Hydroelectric power use is in Austria, because of the excellent geographic situation of highest importance.

The total electric power consumption in Austria was:

1990: 49 TWh

2006: 67 TWh

Actually in Austria are:

38 TWh/year

produced by waterpower.

This is equivalent to about 58 % of the total Austrian electric power consumption.

About 5,5 TWh or 14% of Hydropower or 8 % of the total Austrian electric power consumption is produced by small hydro power plants. Austria has a total potential in hydropower to produce electricity of about 57 TWh.

Therefore the theoretically useable potential of enhancement in waterpower is about +/- 19 TWh. From this amount are with respect to ecological reasons about 5 TWh under no circumstances useable.

Therefore a usable potential of 14 TWh will remain.

According to an estimate of the Austrian energy suppliers and Small Hydro Power Austria it is realistic to realize 7 TWh until the year 2020.

2 TWh of these 7 are to realize in the area of small hydro power plants and – this is the message – 0.7 TWh of these 2 TWh are realizable in the field of already existing Small hydro power plants by updating and revitalization. The thesis shows the possibilities to gain the resources of existing small hydro power plants using an old small hydro power plant in Styria as an example. The revitalization of existing old small hydro power plants is a very gentle method and defensible in the view of ecology.

[1)] All figures from “Verein Kleinwasserkraft Österreich” Vienna

1.1 Motivation

My motivation to write this thesis is very close linked to my lively interest in the field of renewable energies.

I am deeply persuaded of the necessity to invest all what is possible to boost the field of renewable energies, in sciences as well as economy. Both is necessary to make renewable energies accessible to a broad clientele.

I was always, also in my childhood, fascinated by waterpower. Concerning this matter Austria is a privileged country and we should use these excellent potentials.

The family of my daughter in law actuates several small hydro power plants in Styria. When I found out that one of these power plants, a really small one, has been operating virtually in the original condition since 1937 I came to the decision to write my thesis about this power plant. The circumstance, that this power plant was built in the year 1937 in place of an older power plant constructed in the very early years of the 20th century, has affected myself to investigate in the historic points of using waterpower for industrial purpose in the geographic area we describe.

1.2. Core Objective of work

The core objective of this thesis is to demonstrate that it is worth to invest in existing, sometimes very old, small hydro power plants, because it is possible to get an interesting economical return in form of remarkable increases of performance of these plants.

The thesis will answer the questions:

Which tools are used in the field of small hydro power plants ?
How can we increase the performance?
Which rates of increase in performance can we expect ?

The thesis is broad structured to give the reader an overview about technique and the possibilities to renew existing small hydro power plants.

1.3. Citation of main literature

Structural Design of Small Hydroelectric Power Plants
Em. O. Prof. Dipl. Ing. Dr. techn. Dr. h.c . Helmut Drobir
MSC-Programm MODULE 4

Physical Principles of Hydropower use and environmental problems
AO Univ. Prof. Dipl. Ing Bernhard Pelikan
MSC-Program MODULE 4

Mechanical and electrical equipment for small hydropower plants
Ing. Werner Panhauser
Ing. E. Kössler GmbH

Water resources assessment
Univ. Prof. Dr. Günter Blöschl
TU Wien

Handbuch zur Planung und Errichtung von Kleinwasserkraftwerken
Übersetzung Prof. Pelikan
ESHA 2004

1.4. Structure of work

The thesis allows a short view in the local history of using hydropower, also about the industrial history of this area and gives short information about history and the fundamentals in the applied techniques.

The core is to show which technical and river engineering measures can be taken to renew existing small hydro power plants and how to increase their performance. The thesis will do it by using the so named “Vincenz turbine”, a small hydropower plant built in 1937 and which is until today in the original shape and is using the original equipment.

In this special case, without dismantle the turbine, turbine controller and generator; it is only possible to estimate the expected results. But very close to Power Plant “Vincenzturbine” is a second one, Power Plant “Margaretenhütte”. This one was already renovated in the year 2006. Here are all figures available, also the estimated figures before renewing measures began.

Therefore, it is possible to compare the proven results from “Margarentehütte” with those from Power Plant “Vincenzturbine” and to check them for plausibility.

We use these results to check our estimated figures we have for “Vinzenturbine” for plausibility.

2. Background Information

2.1. Geographic Background [2])

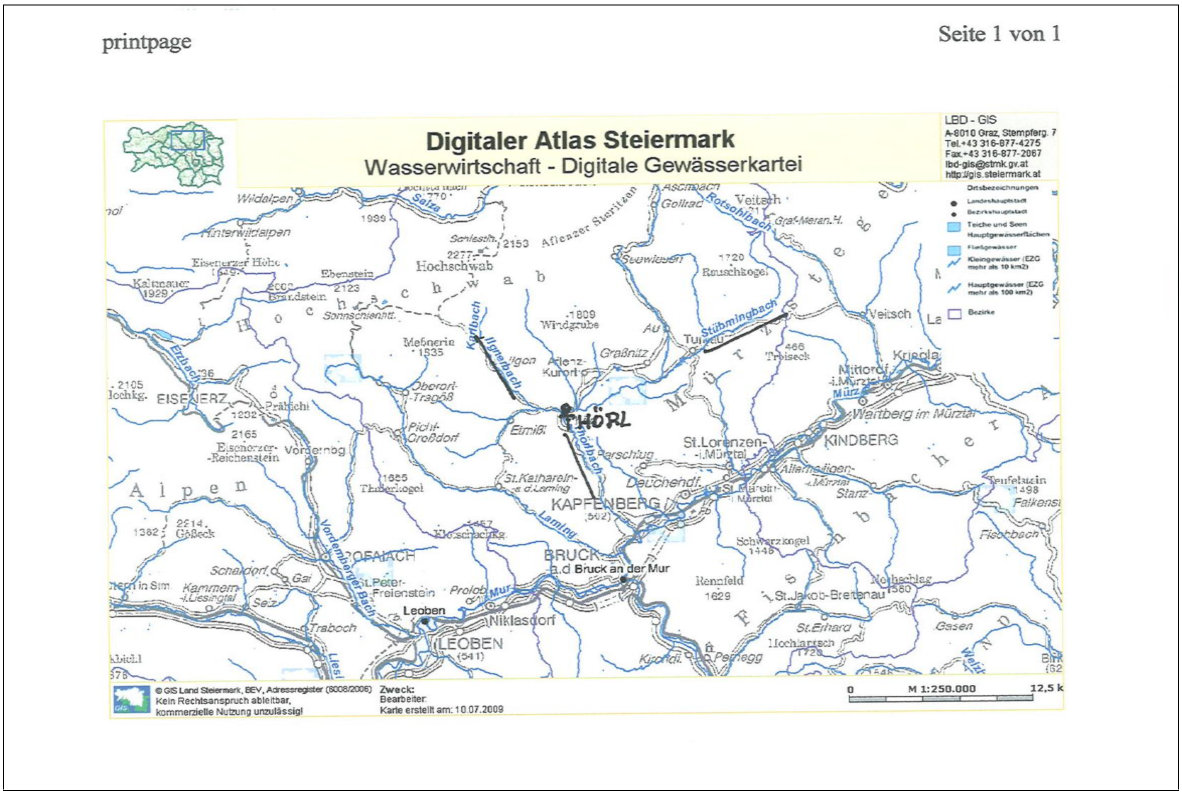


Figure 1 Atlas Steiermark, Wasserwirtschaft, Gewässerkartei

Two small rivers – Stübmingbach and Ilgnerbach – will unify in Thörl to the Thörlbach. The catchment area of this system consists of Hochschwabmountain and Mürzsteger Alpen. The small hydropower plant named "Vincenz Turbine" is situated on the Ilgnerbach, 20 m before it flows into the Thörlbach. The small hydro power plant "Margaretenhütte" is situated 5 km downstream at the Thörlbach.

[2]) Geogr. Informationssystem GIS Land Steiermark

2.2. The industrial history of Thörl/Styria/Austria [3)]

Figure 2: early industrial time, Ironworks Thörl

The secured industrial history of Thörl and the history of iron extraction in this community started in the year 1372. In this year the chevaliers of Waldstein operated already a hammer, driven by waterpower in Thörl and paid an interest to the monastery of St. Lamprecht, Upper Austria. The years passed by, the hammer still in operation.

In the year 1469 a new situation: Thörl became the armourer of the Austrian monarchy. For the first time ever Thörl was the place where forged, hammered guns were produced.

The Austrian emperor Maximilian boosted the extension of Thörl to the center for constructing big guns. The small village “Büchsengut” is a reminiscence of these old times.

[3)] Maja Löhr: Geschichte eines steirischen Eisenwerkes, Verlag für Politik und Geschichte Wien 1952

The tradition of steel treatment leads through the centuries. In 1805 Vincenz Pengg bought the hammer and the steel industry in Thörl. A water driven hammer was used until the first years of the 20th century. The family Pengg-Auheim saved its holdings and formed the industrial landscape in the valley between Thörl and Kapfenberg.

Steelworks and hydropower plants along the river Thörlbach are telling a story of success. Two of these hydropower plants are in the focus of this Master thesis.

In 1926 power plant " Margaretenhütte" was built. This plant was renewed in 1966 and a second time in 2006 and is later described in detail.

In 1937 the smaller power plant "Vincenzturbine" was built, this one is in this respect a rarity, because it is in the most modules in its original condition. The thesis will investigate the possibilities to increase the efficiency of this plant.

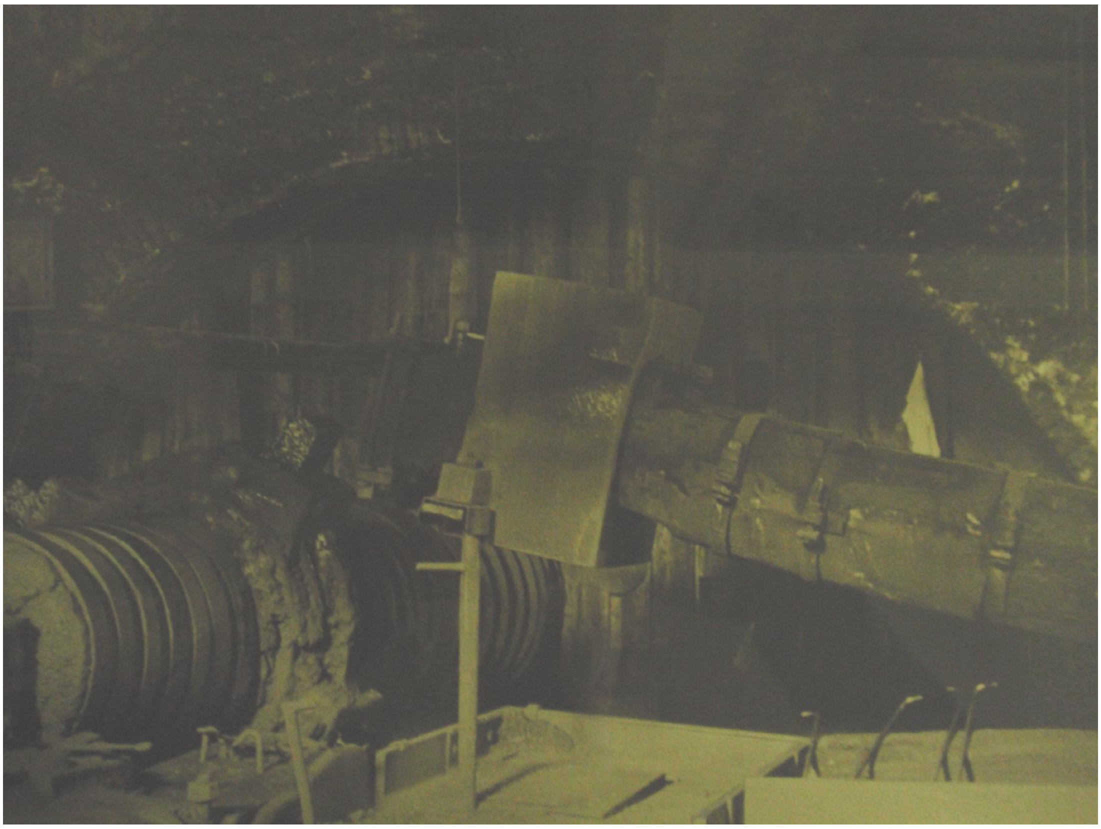


Figure 3: the last old hammer driven directly by water power and in use until 1921

2.3. The history of water turbines

The history of modern water turbines is inseparably associated with Austrian engineering and the name of Victor Kaplan (1876-1934).

We can say the history of modern water turbines began in 1844, when Uriah A. Boyden developed based on the Fourneyron turbine a new model of which the runner shape was already similar to that of the Francis turbine.

In 1849 James Francis improved the first modern water turbine. For many years, it was the market-dominating turbine. In 1866, Samuel Knecht invented a turbine, working on a different concept:

Knight used water jets and the energy of water coming hundreds of meters in a pipe or penstock.

Later in the year 1879, Lester Pelton developed out of the Knight wheel a double bucket design, which exhausted the water sideward’s. In 1895, William Doble improved Peltons model to the present modern form.

In the year 1913, Viktor Kaplan got his patents for his turbine. The first Kaplan-turbine was built in the year 1918 and was put in operation in the 1919 in Velm, Lower Austria. It worked there until 1955. Now it is placed in the Technical museum, Vienna. Today the Kaplan turbine is used all over the world.

2.4. Definition of small hydro power plants and the substantial devices.

2.4.1 Definition of Small hydro power plants

Most countries in EU-Europe use a 10 MW-limit to define a small hydro power plant. (In Austria, we define up to 15 MW the plant as a small hydro power plant). In non-European countries, the limits differ in a wide renage from 25 to 390 MW.

2.4.2 Site configurations [4)]

The objective of a hydropower scheme is to convert the potential energy of a mass of water, flowing in a stream with a certain fall to the turbine (named the head) into electric energy at the lower end of the scheme, where the powerhouse is located.

The power output is proportional to the flow and to the head. We can generally classify according to the "head":

- High head 100 and above
- Medium 30 - 100 m
- Low head 2 - 30 m

These ranges are not rigid.

We also can define

- Run of river-plants
- Plants with the powerhouse located at the base of the dam
- Plants on a canal or a water supply pipe

Small hydro power plants very often use the type of a diversion plant, also both small hydro power plants which are in the centre of this thesis, represent this type.

[4)] Handbuch zur Planung und Errichtung von Kleinwasserkraftwerken, Übersetzung Prof. Pelikan ESHA 2004

2.5 A diversion plant consists of:

a) A Weir

Is necessary to retain the water of the river and raises the head. Usually it is constructed as sluice weir with sliding panels. In the case of small plants, wooden panels are used very often. If large hydro power plants are constructed, it is indicated to use steel constructions. Usually electronic or hydraulic actuators drive the mechanics. In the case of bigger hydro power plants flap gates can be used.

b) Fish ladder

In the case of a new small hydro power plant the fish ladder is a must to get the authorisation. There are many types possible, to choose the right one is dependant of the local circumstances. Since years it is a demand, that not only fishes should have the possibilities to migrate, also small animals should have the chance to do so. It is alos necessary to secure, that the fish ladders are usable in both directions.

c) Intake structures

The intake structures are necessary to conduct water to the penstock without – or at very low – losses in head. There are two different possibilities:

- The intake is the begin of the penstock to the turbine
- The intake is the begin of a channel or a tunnel and leads to the begin of the penstock.

Besides of that we have also to see the necessity to minimize environmental problems e.g. fish ladders, minimizing disturbing effects to the characteristic features of the immediate environment and so on.

The most important problem is to avoid that different material, sediments and biological waste can come into the turbine. To clean the water from sediments, sediment traps are used. To clean the water from different debris, trash racks are used. This device exists in a very simple form manual cleaning or more sophisticated available in automated versions.

Usually a rack with widely mounted bars is used on the weir, later, just before the intake, a fine screen is used. A clogged rack can minimize the performance of a turbine significantly.

d) Turbine [5)]

Turbine selection criteria:

- The turbine is the core of a hydropower station. The economical success of the hydropower plant is depends on the right choice of the turbine.

- The type, geometry and dimensions of the turbine will be fundamentally conditioned by the following criteria:
    - net head
    - range of discharge through the turbine
    - rotational speed
    - cost

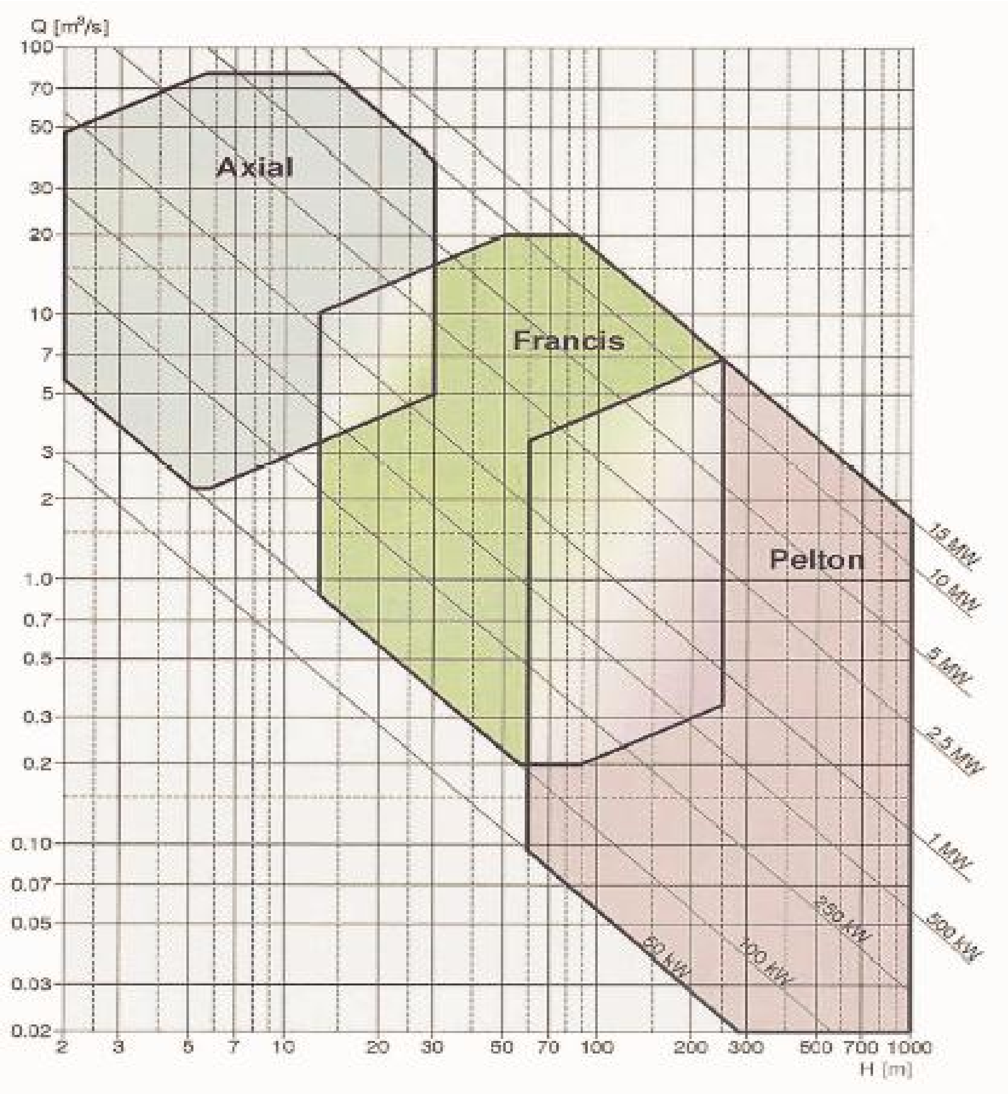
The first criterion to take into account in the turbine selection is the net head.

Table 1 specifies the range of operation head for each type of turbine. The table shows some overlapping, for a certain head, several types of turbines can be used.

Table 1: Range of Heads	
Type of turbine	**Head range in meters**
Kaplan+Propeller	2 - 40
Francis	25 - 350
Pelton	50 - 300
Crossflow	5 - 200
Turgo	50 - 250

5) Handbuch zur Planung und Errichtung von Kleinwasserkraftwerken (ESHA 2004)

Figure 4 Turbines' type field of application



The rated flow and net head determine the set of turbines types applicable to the site and the flow environment.

Suitable turbines are those for which the given rated flow and net head plot are within the operational envelopes. (Figure 3). A point defined as above by flow and head will usually plot within several of these envelopes. All of those turbines are appropriate for the job.

If will be necessary to compute installed power and electricity output against costs before making a decision.

It should be remembered that the envelopes vary from manufacturer to manufacturer and they should be considered only as a guide. As a turbine can only accept discharge between the maximum and the practical minimum, it may be advantageous to install several smaller turbines instead of one large turbine.

Sharing the flow between two or more units will also allow higher rotational speed and will reduce the need for a speed increaser.

Table 2 Flow and head variation acceptance		
Turbine type	**Acceptance of flow variation**	**Acceptance of head variation**
Pelton	High	Low
Francis	Medium	Low
Kaplan double regulated	High	Medium
Kaplan single regulated	High	Medium
Propeller	Low	Low

Modern small turbines in general have very good efficiencies; the figures in table 3 are valid for new turbines.

Table 3 Maximum efficiency of modern turbine types	
Turbine Type	**Best efficiency**
Kaplan single regulated	0,91
Kaplan double regulated	0,93
Francis	0,94
Pelton	0,90
Turbo	0,85

If the turbine is very old, some Francis turbines are up to 100 years, it can be expected, that the efficiency will be at 80%.

In the case, that a modern, but used turbine should be used, we can calculate with 5 – 10 % less efficiency compared with a new one.

e) Generator

New generators are not expensive. In the case of a general overhaul, it is recommended to buy a new generator.

An example:

A new generator for a 90 KW plan has a price of 8.500€ and a better efficiency of 3%. This means, the electrical efficiency will increase for 2,7 KW. Now, calculating with 5000h/year we have an increase of 13.500 KWh per year. This investment will amortise within 5 to 6 years. This is a strong argument for a new generator.

2.6 How to calculate the capacity of a Hydropower Plant:

Capacity:

$$P(KW) = Q\ (m^3/s) \times H\ (m) \times \text{tot. efficiency}$$

Tot. Efficiency = eff. Turbine x eff. Generator x eff. Speed increaser x eff. transformer

P = electrical power output

Q = rated discharge

H = net head

and approximately we can calculate:

$$P = Q \times H \times 7{,}8$$

Electricity production:

$$E(KWh) = P(KW) \times 4500\ (h)$$

2. 7 Performance enhancing of long existing water turbines [6)]

2.7.1 Introduction

Hydropower and small Hydro Power Plants have a long history and a large number of them is existing, still using old types of turbines, generators and transformer. In many cases, it can be wise to renew already existing small Hydro Power Plants instead of engineering new plants.

In case of renewing, problems with the public are usually rare and it is much easier to procure all necessary licenses.

The increase of performance can very remarkable and very interesting in an economical view.

2.7.2 Overview of the possible updates to achieve improvements in efficiency

2.7.2.1 The increasing of the water storage level

All possible actions to increase the headwater, especially under use of FRANCIS or KAPLAN turbines can bring some increase in efficiency. If the change in head water is bigger, it is mostly necessary to adapt the rotation speed of the turbine.

2.7.2.2 Minimizing the losses at the trash rack

The effective head of water is the level of water after the rack. Therefore it is of high importance to have an automatic trash rack cleaning machine, which in the case log jam will clean automatically.

[6)] Josef Lampl: Leistungsverbesserungen von bestehenden Wasserkraftturbinen, Kössler GmbH, St. Pölten

2.7.2.3 Prevention of entrapped air at the turbine inlet

This problem can be observed mainly under us of KAPLAN or FRANCIS Turbines. Air in the turbine will reduce efficiency and therefore the performance of the turbine.

2.7.2.4 Revitalisation of turbines

Depending on the type of turbines different measures are necessary. Mostly a complete overhaul or exchange of the control device, respectively the guide vane apparatus will have to take place. In general all the turbines show mostly heavy losses by corrosion and mechanical wear. If spare parts are no longer available different parts have to be manufactured as single parts. Often repair will be done by different welding practices. After such operations it is necessary to reconstruct the original shape or profile of all parts mechanically or sharpening by hand.

In any case the wheel with its hydraulic profile is the core of any turbine and determines the efficiency level.

Abrasion on the vanes will cause a lack of affectivity and occurrence of cavitation damages.

2.7.2.5 Repair of shaft feed troughs and stuffing boxes

As mentioned above, entrapped air in the turbine causes a lower efficiency and therefore a decreased engine power. Therefore in such cases it is necessary to replace or repair these parts.

2.7.2.6 Upgrade of the turbine diffuser (Saugrohr)

a successful operation of the diffuser tube is very important for the overall efficiency of the turbine.

This is valid especially for FRANCES and KAPLAN turbines, in the case of PELTON turbines the positive influence is not significant. Important is also the free run off of water. Sometimes the unsilting in the area of the tailrace will bring good results.

2.7.2.7 Increase of maximum throughput (capacity) of the turbine

In some cases it is possible to optimize the turbine parameters to increase the capacity of the turbine. The necessary steps have to be done very carefully. The danger of cavitation will occur on FRANCIS and KAPLAN turbines if the throughput of water is too high. In the case of PELTON turbines the effect of a “water hammer” can occur.

2.7.2.8 Connector between turbine and generator

In the past the most common method to transform the relatively low speed of turbines to a higher speed of generators was the use of a gear. These gears are long living and robust, but looking for a better efficiency here can be found some potential. Gears of older construction have a slightly worse efficiency because very often they have multiple bearings and therefore higher friction losses.

Modern turbines under state of the art design are either constructed with higher engine speed and a direct coupling to the generator or gears with excellent efficiency are used.

2.7.2.9 Generators

Generators of newer are using better magnetic material, have a better realization in detail and low losses in the electric coils. In addition modern generators have less friction losses. The degree of efficiency of a new generator can be found between 95 – 97 %.

The prices of new generators and gearings are in general relatively low and therefore if the performance of a small hydropower plant should be increased it is a absolute mandatory and appropriate action to replace generator and gearing.

2.7.2.10 Transformer

Modern transformers use better magnetic materials with lower losses in its coils. Therefore, if the transformer is very old we also should think about the exchange against a new one.

2.7.2.11 Turbine controller (turbine control unit)

Older small hydro power plants are using very often mechanic controllers. These types have the disadvantage that if it is a current controller, driven by a belt transmission and is all the time energy consuming. Today we use electro hydraulic turbine controllers. These types offer a much better quality of control and have much less power requirements.

3. Description of method of approach applied

The goal is to find out, which possibilities exist to overhaul the old Small Hydro Power Plant “Vincenzturbine” and to bring it to a better performance. The main items are from 1937 in a very original condition. It is difficult to decide, which percentage of performance increasing is realistic for a certain measure.

To become more realistic, we look first at a second Small Hydro Power Plant, which was renovated already in 2006. We know the estimated figures before and now the actual figures after the overhaul-program and use this as a basis for comparing our estimated figures for Small Hydro Power Plant “Vinzenturbine” and check it for plausibility. This approach opens the way to get some feeling, which percentages in performance increase are realistic.

4. Documentation of data and data collection

4.1 Small Hydro Power Plant “Margaretenhütte”

The hydro power plant “Margarentenhütte” was built in 1926. Unfortunately, it was not possible to get information about the old turbine or other technical measures.

Figure 5 Founders board

Figure 6: Historical board

The historical boards with the dates of founding and redesigns are still in the turbine room. In 1966 a new turbine – Kaplan – bulb turbine (Kaplan-Rohrturbine) and complete new electrical installations cam. The characteristics of the new turbine on the original board:

Figure 7: Nameplate of turbine

and the characteristics of the synchronous generator also in original shape:

Figure 8 Nameplate Generator

This plant was working until 2006, a decision was done to overhaul the complete hydropower plant and also the weir with all facilities.

Fortunately, all these activities and transactions are documented and described in detail, some pictures will allow to understand the objective operations.

An expertise of a private engineering office – Kanzlei DI Karl Michael Pittino, Graz, dated 7.12.2006 evaluates the impact of the several structural measure, technical an driver engineering works.

Preliminaries:

The Johann Pengg Holding GmbH in Thörl 35 is the operating company for the small hydropower plant, “KW Margaretenhütte” on the Thörlbach, which is indexed in the water register of the region Bruck/Mur under figure 223.

In the year 2006 measures of revitalisation a the power plant Margaretenhütte were implemented. The target was the increase of the achievable standardised working hours per year. (Regelarbeitszeit). The demonstration of the arranged revitalisation and the estimated increase of the standardised working hours per year are contents of this expertise.

Overview of the parts of the power plant

The power plant consists of the weir, the headrace channel on the right bank, the surge tank and a penstock to the turbine, the powerhouse and the tail water.

Technical dates:
KAPLAN-BULB Turbine built by ANDRITZER MASCHINENFABRIK
QA. 5,00 m³ / SEC

Retention water level	614,12 m
Tail water – water table	606,71 m
Head:	7,41 m
Power:	approx. 310 KW

Revitalisation – and the impact assessment

The weir

The bottom of the chute (Schussboden) was renewed and the catch bolts newly sealed and made tight.

Evaluation

The measures around the weir lowered the non-revenue water significantly. The evaluation of the effect to the total efficiency of the plant can be expected with 2 -4 % (empiric).

Headrace

The headrace in direction to the surge tank was unsilted and cleansed of natural cover:

Evaluation:

The measures around the headrace allowed to optimize the stream flow of water. The efficiency of the plant will be increased by 1 -2 % as similar calculations show.

Surge tank

The catch bolts were redeveloped and the spillway new designed.

Evaluation:

The measure in the surge tank brought less losses of water and a better operating reliability. The evaluation of the consequences to the efficiency are difficult, therefore it is assumed with 1 – 2%.

Penstock

The penstock from the surge tank to the turbine is newly built. The inlet guiding cone and the adaptor to the turbine made of steel are in a new aerodynamically efficient design completely new constructed.

Evaluation:

Due to the measures on penstock and inlet guiding cone there is now a flow-enhancing design active and the friction losses are reduced. The evaluation how this will effect the efficiency of the power plant is difficult. Therefore it is estimated from 3-5%.

Turbine:

The Kaplan-bulb turbine got a complete new controller. New is a water gauge control and a differential gauge monitor for the racking machine. The digital control of the plant allows fully automatic starts and stops and auto starts of the plant.

The rinse cycle works also fully automatically.

Evaluation:

The measures on turbine increased the performance significantly. The automatisation of the control system gives a better reliability and availability of the power plant. The impact to the efficiency of this activities – after discussion with Fa. ANDRITZ AG – can be assumed with 8 – 10% .

Generator:

The generator git a general overhaul and a new set of bearings.

Evaluation:

The efficiency increase – after careful consideration – can be obtained with 2 – 3%.

Energy economics

Energy economics old:

according to the statistical records of the operating company Johann Pengg Holding GmbH, the total generation of electricity in the years 2003, 2004, 2005 added up to 4726 MWh, this is an average production of 1575 MWh per year.

Energy economics new – Total efficiency - calculation and increase

Table 4: Total efficiency – calculation and increase

	Lower value in %	Upper value in %
Weir	2	4
headrace	1	2
Surge tank	1	2
Penstock	3	5
Turbine	8	10
Generator	2	3
Total increase	17	26

Therefore a total increase of efficiency can be expected between 17 and 26%.

Under identical average boundary conditions the average production per year should be at 1920 MWh/year (~ +22%)

The power plant “Margaretenhütte new” started on 20.10.2006 again.

Results after three years

Now the dates of 3 another years are available, according to an information of the operating company it is acceptable to assume, that the ambient conditions statistically over the years are comparable.

Here it can be shown, that the antecedent calculations were very precise. The actual value per year – October 2006 .- up to 2009 is 1905 MWh/year.

This corresponds exactly to an increase of 21 %.

4.1 Small Hydro Power Plant “Vincenzturbine”

Figure 9 Vincenzturbine

The Hydro Power Plant “Vincenzturbine” was built in 1937, replacing the old “Elektrizitätswerk Thörl”.

The specific feature or this plan is the fact, that the whole unit is up to date in the original condition. Unfortunately, repair works in earlier years are poorly documented. But informed people attest, that beside of bearings and diverse sealings no repairs took place.

Figure 10: Hydro Power Plant Vincenzturbine front view

The characteristics of the Small Hydro Power Plant Vincenzturbine:

H = 9,2 m

Q = 1220 lit/sec (870)

P = 120 PS = 91 KW

N = 460 p / min.

The weir:

The weir is in place of the older weir of the mentioned Elektriziätswerk Thörl.

Figure 11: The weir

To the left the headrace channel leads to the intake of the tubing. At the begin of the headrace channel there is a wooden rack with wide distances between the bars.

Figure 12: Vincenzturbine: Headrace channel

The length of the headrace channel is about 200 m, it leads directly to the intake.

Figure 13: Vincenzturbine: The Intake with the fine screen

What is used as a intake is part of the old “Elektrizitätswerk Thörl “ (it is a part of the old surge tank). The very simple rack is to be cleaned manually several times a day. Right-hand we see the desander device.

Figure 14: Vincenzturbine: The surge tank

The penstock, a 1100 mm tubing with a length of 380m leads directly to the tower with 11m height with the function as a surge tank. From the tank a short tube connects to the turbine.

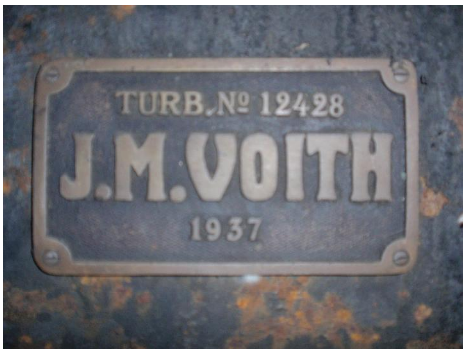


Figure 15: The original label

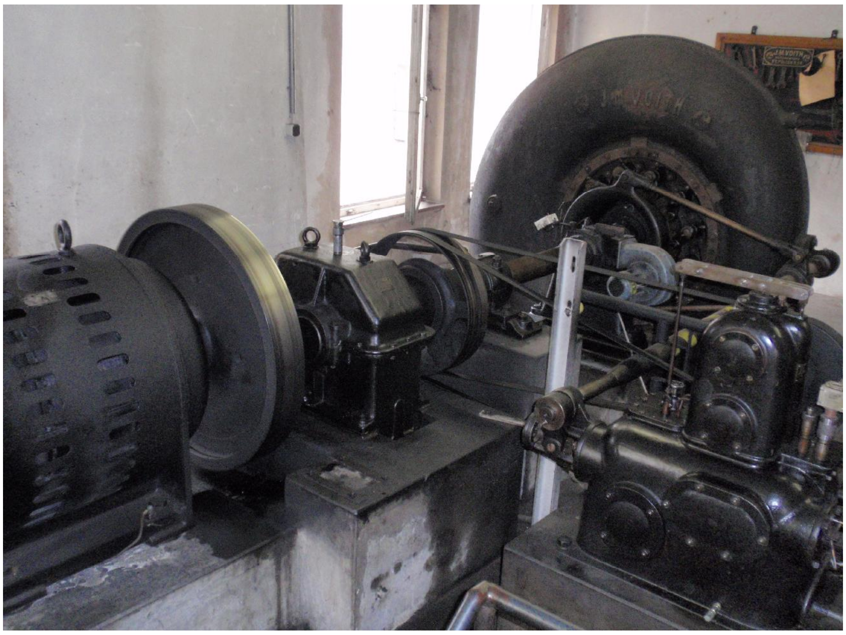


Figure 16: Vincenzturbine: The turbine generator unit

The picture shows turbine, generator and the mechanical turbine controller, the belt transmission is easily to be seen.

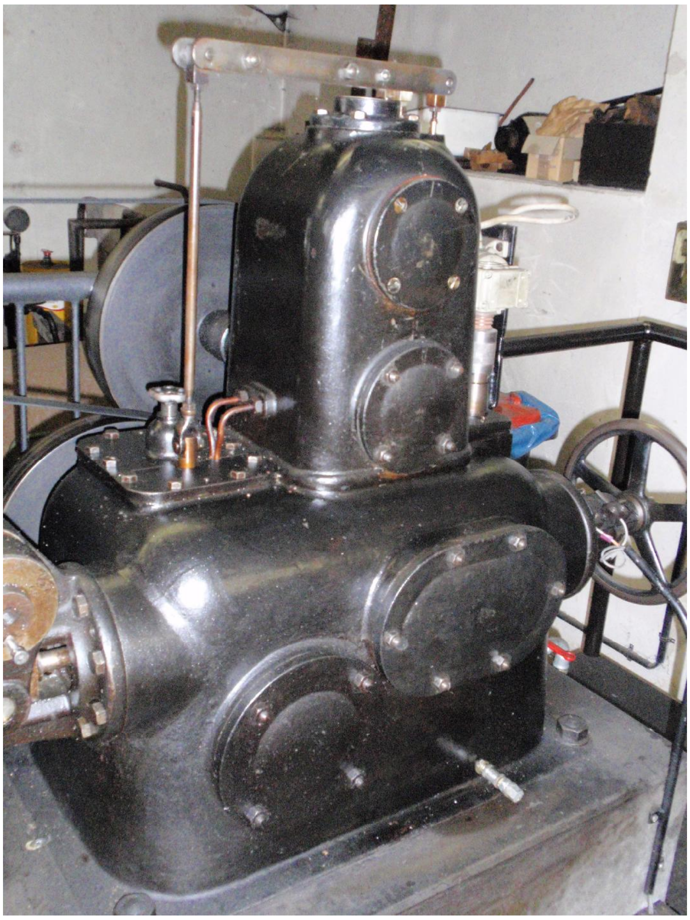


Figure 17: Vincenzturbine: Mechanical turbine controller

The board with tools underlines the original condition of the whole plant; most of it is still existing.

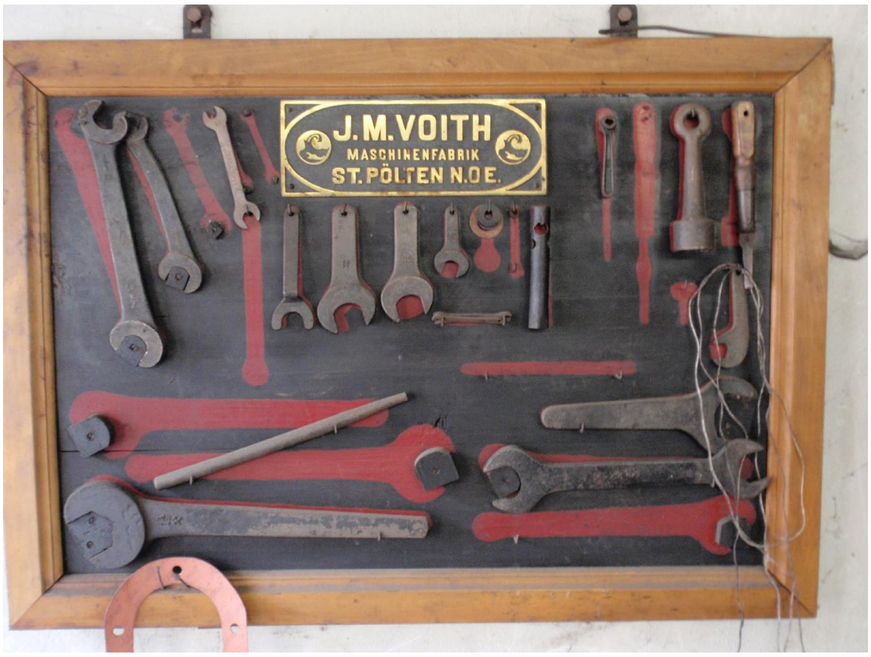


Figure 18: Vincenzturbine: The original tools from 1937

The electrical system – except the generator – got a face-lifting and reaches modern standards.

Figure 19: Vincenzturbine: The electrical system

Revitalisation of the Vincenz Turbine – and the assessment of its impact

The weir

is in good condition.

Evaluation

No measures are to be taken.

Headrace:

The headrace in direction to the intake is clean and in a good shape.

Evaluation

No measures are to be taken.

Intake structure

The intake structures and the existing rack, which is manually to be cleaned, are the main problems of the Vincent Hydro power plant. What is used as an intake, is the lower part of the surge tank of the former old Hydro Power Plant "Elektrizitätswerk Thörl"

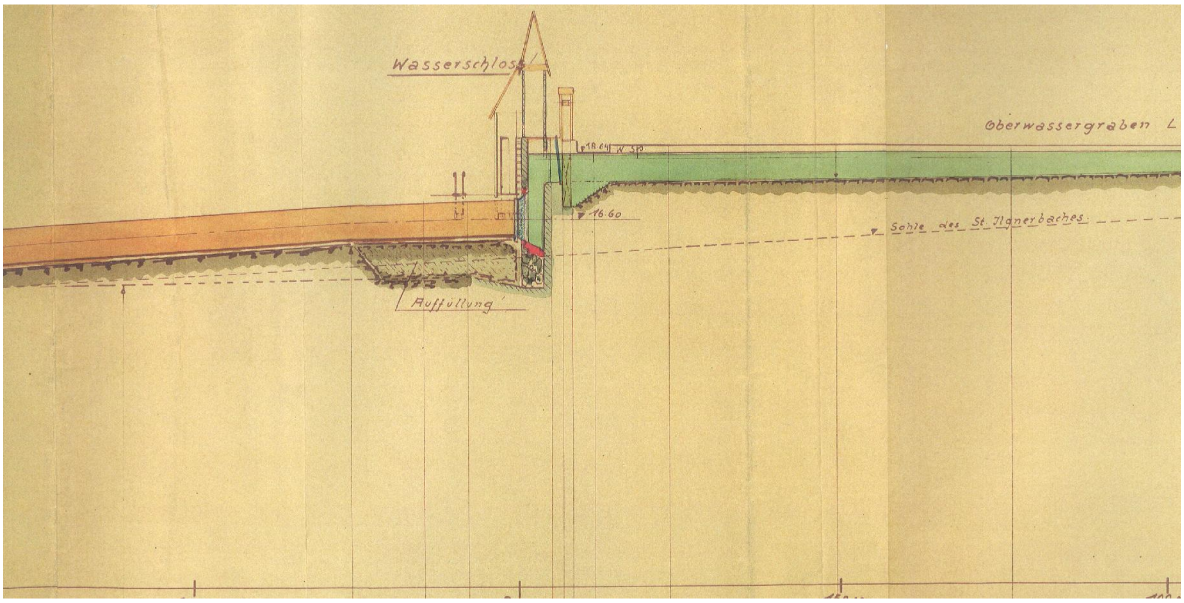


Figure 20: "Wasserschloß" Elektrizitätswerk Thörl

It is difficult to believe, that the flow conditions in this system could be optimized. The second point is the insufficient and unsatisfactory form of the rack. It seems to be necessary to reconstruct the whole intake structure and to use a modern, automatic rack cleaning machine.

Evaluation:

It is difficult to evaluate the flow situation, but the influence of a modern rack can be assumed with 5 – 10 %.

Penstock and Surge tank:

The current state of penstock and surge tank is good.

Evaluation

No measures are to be taken.

Turbine:

As already mentioned, the turbine has an age of 72 years. The actual status of the turbine can only be surveyed, if the turbine is completely demounted. As a matter for principle it can be said, that every turbine can be overhauled. Usually it will run afterwards for many years. We can assume, that an old Francis turbine has a worse efficiency; modern turbines will have better values.

Evaluation:

We assume that the efficiency of an overhauled turbine will increase by 5 - 8%. In the case, that the turbine will be replaced by a new one, we think, that the efficiency will increase by 5 - 12%. We calculate the efficiency of the present turbine in the current status will be about 75%. Unfortunately, there was no possibility to check the tailrace area. The old schema shows a part, it could be a diffuser, it would also be useful to check the situation beyond the turbine, and sometimes it brings good results to unsilt the tailrace.

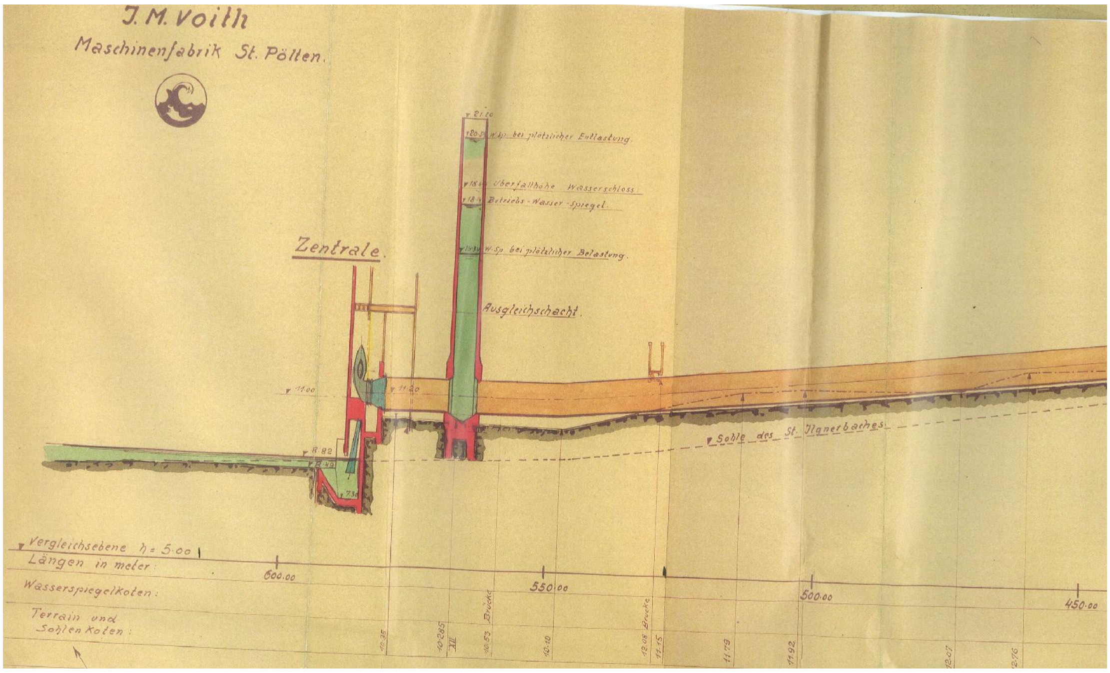


Figure 21: Zentrale Originalplan J.M. Voith

Generator

If a turbine will be replaced, it is obvious to change also generator and gearings. The time of amortization is relatively short.

Evaluation:

A new generator and new gearings will bring 2 – 3 %.

Turbine controller

The mechanic turbine controller should be changed against an electronic controlled device. Mechanic systems are powered all over the time and therefore they are always energy consuming.

Evaluation:

A modern controller will save 2 – 3 %.

Energy economics

Energy economics presently:

According to the statistical records of the operating company the yearly generation of electricity in the years 2006/2007/2008 were in average 290 MWh.

Energy economics suggested:

Total efficiency - calculation and increase

Table 5: Total efficiency – calculation and increase

	Lower value in %	Upper value in %
Weir	-	-
headrace	-	-
Intake with rack	5	10
Surge tank	-	-
Penstock	-	-
Turbine overhauled	5	8
(Turbine new	*8*	*12)*
Generator new	2	3
Turbine controller	2	3
Total increase	14	24
(Total increase with new turbine	*17*	*28)*

5. Description of results

What do the results mean:

Revitalising the old turbine, we have a production increase of

Lower Value	**Upper Value**
MWh/year	MWh/year
40,6 (14%)	69,6 (24%)

and using a new turbine

49,3 (17%)	81,2 (28%)

Now, using our experience with “Margaretenhütte” (a range from17 to 26%) and our estimates concerning “Vincenzturbine” (a range from 14 to 28%) we can do the careful conclusion, that an increase of effiency in the case of old Small Hydro Power Plants in the range of 20% is realistic.

Modern techniques offer a broad range of possible solutions, but it is necessary to match it against economics. So, for example, this thesis gives an evidence in technical visibility and postponed economical considerations.

But it should be possible to find for each old Small Hydro Power Plant an appropriate solution for revitalisation and better results. Maybe the measures should be taken step by step sometimes. Each power plant has its own identity and needs its own solutions.

At the end a few personal words:
My investigation in Styria showed me the world of Small Hydro Power Plants, I saw, how harmonic technique and nature can be created and I believe in it.

I want to finish with the picture of the water storage area from “Margaretenhütte”, where I had a “meeting” with three white herons (weisse Reiher) and where I saw the largest trouts in my life.

References

1) (Page 6) Verein Kleinwasserkraft Österreich

2) (Page 10) Geographisches Informationssystem des Landes Steiermark

3) (Page 11) Marja Löhr, Geschichte eines steirischen Eisenwerkes (Verlag für Politik und Geschichte)

4) (Page 14) Handbuch zur Planung und Errichtung von Kleinwasserkraftwerken, Übersetzung Prof. Pelikan ESHA 2004

5) (Page 16) Handbuch zur Planung und Errichtung von Kleinwasserkraftwerken, Übersetzung Prof. Pelikan ESHA 2004

6) (Page 20) Josef Lampl: Leistungsverbesserungen von bestehenden Wasserkraftturbinen, Firma Kössler GmbH, St. Pölten