schrittweises Niederlegen der Klappe der Wehrschütze konstant halten. Dadurch wird für diese erste Phase der Grossteil des Geschiebes im Stauraum deponiert und das anfallende Geschwemmsel wirkungsvoll über die Klappe abgeleitet.
Wenn die Klappe bei Überlauf von 25 m^3/s vollständig niedergelegt ist, wird das Wehrsegment automatisch hochgezogen, um die ungehinderte Durchführung durch den Stauraum der grossen Geschiebefracht mit Blöcken bis über 1 m^3 Inhalt zu ermöglichen.
Üblicherweise wird jedoch das Wehrsegment bereits vor Erreichung der 25 m^3/s durch Handsteuerung an Ort oder Fernsteuerung von der Zentrale Siebnen aus angehoben, um den Geschiebetransport durch das Wehr rechtzeitig einzuleiten. Die oben erwähnte Verengung des Stauraumes ergibt grössere Durchflussgeschwindigkeiten während des Spülvorganges und bewirkt, dass praktisch keine Verlandungen im Stauraum zurückbleiben werden.

Elektromechanische Ausrüstung

Für den vollautomatischen Betrieb der Wasserfassung sind die nachfolgend aufgeführten elektromechanischen Ausrüstungen erforderlich.

Wehrschütze

Von der Segmentklappenschütze (12 m lichte Weite, 2,62 m Verschlusshöhe des Segmentes und 1,1 m Verschlusshöhe der Klappe) wird das Segment beidseitig durch Rückzugpressen betätigt. Die Überfallklappe wird durch eine Druckpresse in Klappenmitte hochgehalten. Seitenschilder, Schützenkasten und Dichtungsflächen sind mit Heizungen ausgerüstet.

Kiesablassschütze

Die unter dem neuerstellten Überlaufrücken am Entkieserende als Spülorgan angeordnete Kiesablassschütze von 1,2 m lichter Breite und 1 m lichter Höhe wird durch eine doppelt wirkende Presse betätigt.

Antriebseinheiten

Das Wehrsegment, die Überfallklappe und die Kiesablassschütze werden unabhängig voneinander durch separate ölhydraulische Pumpenaggregate betätigt. Die Einheiten sind auf einem gemeinsamen Ölreservoir aufgebaut und mit den zugehörigen elektrischen Schalttafeln im hochwassersicheren Bedienungsraum über dem Entkieser eingebaut.

Mess- und Steuereinheiten

Die Wasserspiegellage im Stauraum wird über ein Lufteinperlsystem mittels Druckwaage gemessen. Die Drehwinkelstellungen des Segmentes und der Überlaufklappe der Wehrschütze werden gestängelos mittels Winkeltransmitter erfasst. Die Hubstellung der Kiesablassschütze wird nur als Positionsmeldung Offen – Zwischenstellung – Geschlossen mittels Endschaltern ermittelt. Die Schichtstärke der Geschiebeablagerung im Entkieser wird durch einen Echomaten gemessen.
Die Wehrautomatik sorgt für die Konstanthaltung des Normalstauspiegels bei Wasserdurchflüssen von mehr als 5 m^3/s, für das Niederlegen der Klappe zur Geschwemmselabfuhr und den Hub des Segmentes für die Kiesabfuhr. Die Spülautomatik für die periodische Entfernung der Geschiebeablagerungen im Entkieser wird durch den Echomaten ausgelöst.

Sicherheitsvorichtungen

Bei Ausfall der Zufuhr der elektrischen Energie kann das Wehrsegment über ein ölhydraulisches Gleichstrompumpenaggregat jederzeit gehoben werden. Die Anlage ist mit Batterie, Ladegerät und Zubehör betriebsfertig angeschlossen. Das Niederlegen der Überfallklappe erfolgt selbsttätig bei Überschreitung des Normalstaus um eine einstellbare Grösse durch Öffnen des Ölablassventiles mittels eines Spezialschwimmers.
Eine wesentliche Verbesserung des Betriebes wird durch die vorgesehene Fernüberwachung und Fernsteuerung von der Zentrale Siebnen aus erreicht.

Bauprogramm

Mit den Umbauarbeiten wurde im Herbst 1979 begonnen. Um den Dauerbetrieb der Wasserfassung sicherzustellen, sind verschiedene Bauphasen notwendig. Die ganze Anlage wird im Oktober 1980 betriebsbereit sein.
Die Sandausscheidung im Entkieserbecken ist nicht stark verbessert worden. Das Projekt wurde jedoch so ausgelegt, dass in einer zweiten Etappe der Entkieser durch 2 Entsandungsanlagen mit bedeutend feinerer Sandausscheidung ohne irgendwelche Änderungen an den neuen Bauwerken ersetzt werden kann.

Am Umbau der Fassung Trepsenbach beteiligte Firmen.
Bauherr, Bauleitung: AG Kraftwerk Wägital, 8854 Siebnen. Projekt, Oberbauleitung: Nordostschweizerische Kraftwerke AG, NOK, 5401 Baden. Bauunternehmung: Schnellmann Marcel, Bauunternehmung AG, 8853 Lachen. Schützen: Moesch Schneider AG, Stahlbauschlosserei, 5000 Aarau (Berater: Lothar L. Streuli, 8049 Zürich). Wehrhydraulik: H. Bieri AG, Maschinenfarbrik, 3097 Liebefeld- Bern. Mess- und Registriereinrichtungen: Franz Rittmeyer AG, 6300 Zug.

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Small Water Power Stations in Sweden

Sten Lasu [1]

Resumé: Petites centrales hydrauliques en Suède

A la fin du XIXe et au début du XXe siècle, un grand nombre de petites centrales ont été construites en Suède, comme dans beaucoup d'autres pays. Ces centrales ont perdu de leur importance avec l'apparition des techniques de transport d'électricité sur de grandes distances. Un jour est venu où elles n'ont pu soutenir la concurrence des grandes centrales construites sur les fleuves à fort débit, principalement dans le nord da la Suède, et elles ont été fermées à un rythme croissant.
Devant la crise du pétrole des années 70 et l'envolée des prix de l'énergie, l'Association suédoise des producteurs d'électricité a recensé les centrales de petite puissance, entre 100 et 1500 kW, afin de connaître leur potentiel énergétique. Elle a constaté que la production potentielle globale de ces centrales était d'environ 2 TWh par an. Ce chiffre, qui comprenait l'énergie produite par les centrales encore en fonctionnement mais en mauvais état, justifiait un sérieux effort pour remettre en marche les centrales abandonnées et asseoir leur position dans le réseau suédois.
Pour abaisser le prix du matériel, de l'exploitation et de l'entretien, quelques types de turbogroupes automatiques

[1]) Paper transmitted by the Government of Sweden, prepared by Mr. S. Lasu of the Swedish Power Association. Symposium on the Prospects of Hydroelectric Schemes under the New Energy Situation and on the Related Problems. Athens (Greece), 5th–8th November, 1979.

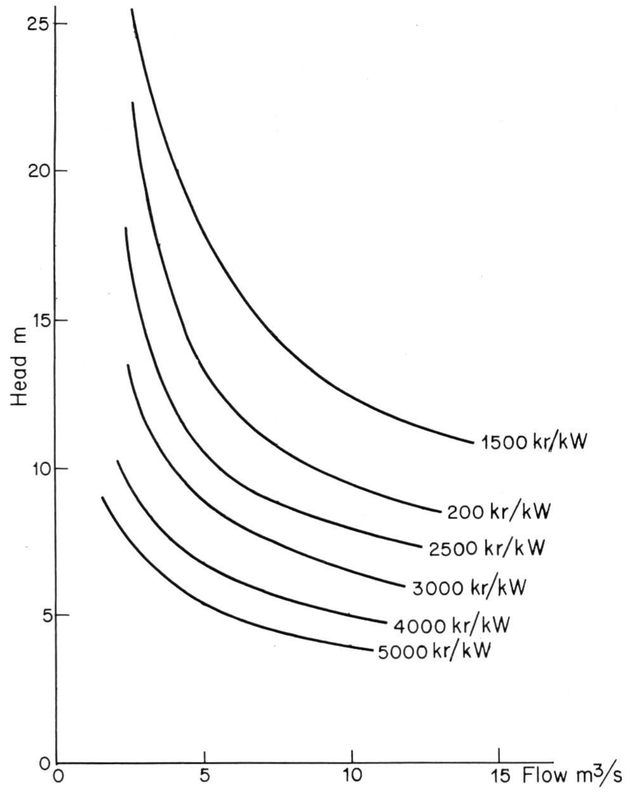

Figure 1. Specific costs of mechanical and electrical equipment for mini power stations. 100 sKr. = 40 sFr. (April 1980).

simplifiés ont été mis au point. Les groupes sont normalisés et requièrent très peu d'entretien. Malgré cela, il a été souvent difficile de justifier économiquement les centrales. Pour cette raison, les propriétaires de ces centrales peuvent obtenir de l'Etat des subventions allant jusqu'à 35 % des coûts d'installation. Une condition pour obtenir cette subvention est toutefois que le projet soit rentable pour l'économie du pays. On prévoit de reconstruire et de rééquiper dans les dix prochaines années quelques centaines de ces petites centrales.

Introduction

In Sweden, as in many other countries, the practical exploitation of electrical energy from hydroelectric power stations began at the end of the last century. The first power stations were usually built where there had previously been directly powered hydraulic machinery for various purposes (mills, saws, hammers, etc.) The power stations were small and essentially intended to supply energy to manufacturing estates or communities in the immediate vicinity. Many hundreds of such small local hydroelectric power stations were constructed, above all in Southern and Central Sweden.
When the alternating current technique had been developed at the beginning of the twentieth century it became possible to transmit electrical energy over increasingly long distances. This led to the awakening of interest to exploit the major rivers, mainly in Northern Sweden, with their rich water resources. Relatively large power stations were constructed along these rivers. During one period large power stations were being built in the great rivers and small power stations in their tributaries, in small rivers and streams. In the course of time, however, a technology was evolved for the construction and operation of the large hydroelectric plants which made the supply of electrical energy from these plants much cheaper than power from the small stations. The greater part of Sweden's electrical energy was gradually taken from the big plants and the rates were determined by the costs of these plants. The result was that the earnings of the small plants were so low that it became impossible to cover the costs for reconstruction when the stations became worn down and out-of-date. The small power stations were therefore scrapped at an increasing rate.
In connection with the oil crisis in the 1970's and the marked rise in energy prices the Swedish Power Association took the initiative in a development scheme for small power stations. In order to investigate the potential energy resources to be found in closed-down small power stations a nation-wide survey was carried out. Power companies and electric utilities in Sweden were asked about both discontinued small power stations and small power stations still in operation but which were believed to require a complete renovation in the immediate future. The survey was restricted to power stations in the class 100 – 1500 kW. The limits were chosen with respect to the assessment that power stations with a capacity of less than 100 kW would require unreasonably high restoration costs whereas very few power stations with a capacity of more than 1500 kW had been dismantled.

The survey yielded the following results

	Number of units	Capacity MW
Closed-down power stations	510	235
Power stations built before 1950 still in operation	684	290
Misc. objects	156	25
	1350	550

If the closed-down stations according to this study were restored and if we assume an average utilisation time of 4000 hours we should then have an energy production of the magnitude of 1 TWh per year. The renewal of plants still in operation would mean no additional energy, but if no measures were taken it would be necessary to reckon on a loss of energy amounting to about 1 TWh per year. The aggregate potential energy output of mini-power stations in Sweden is thus approximately 2 TWh per year. The total electrical power production is about 85 TWh per year, of which about 60 TWh normally comes from hydroelectric power stations. The amount of energy forthcoming from small power stations is thus not very impressive. On the other hand, it represents a domestic source of energy and one which restricts the use of imported expensive fuel oil. The Swedish Power Association therefore considered it worthwhile to make a serious effort to reduce the costs for small hydroelectric power stations and thereby secure their place in the Swedish energy system.

Engineering

One condition for the restoration of the closed-down power stations is that their dams can be used without it being necessary to undertake an excessive amount of reinforcement work. Another important condition is that it should be possible to refer to earlier decisions by water rights courts in order to limit legal processes.
Development was concentrated on both reducing costs for mechanical and electrical equipment and also lowering the costs of maintenance and operation. The idea was that by means of simplification and standardisation to reduce capital costs and by means of automatisation to reduce operating costs. It was in fact the high costs of operation for the older plants which led to their being closed down and the high specific renovation costs which prevented their restoration.

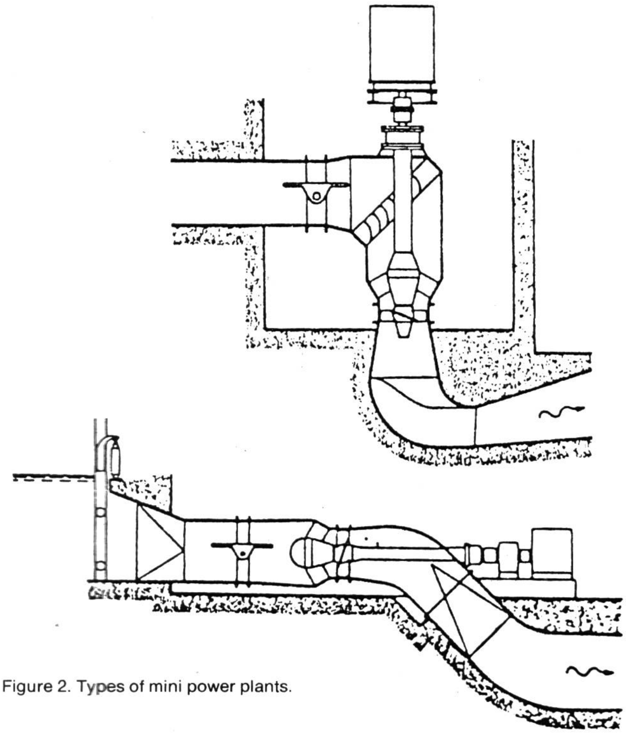

Figure 2. Types of mini power plants.

Most Swedish small power stations work with heads of 3–15 m. From fig. 1, which indicates the relationship between head, flow and costs, it may be seen that the specific costs increase markedly with a fall of head. This means that all possibilities of achieving cost-saving simplifications of equipment must be utilised. Since a relatively large number of stations could be constructed, consideration must be given to the possibilities of standardization in order to profit from the advantages of serial production.

For most of the closed-down power stations there are possibilities of regulating the water storage belonging to the station and thereby operating the plant intermittently. This makes it feasible to eliminate the turbine regulator and equip the turbine with fixed runner blades. Nor is a guide vane apparatus necesssary: fixed vanes may be used instead. A further simplification is as generator to use an ordinary asynchronous machine run at supersynchronous number of revolutions. One limitation of the asynchronous machine is that it must take its frequency from the general electricity grid and cannot be operated independently of this. This disadvantage is of a minor nature, at least in Sweden, where we have a nation-wide power network with very high reliability of supply. By choosing the asynchronous machine we eliminate the need of a voltage regulator. Instead we require a battery of capacitors to magnetize the generator in cases when we cannot take the reactive power from the power network. This is compatible with our endeavour to reduce maintenance requirements and allow the station to consist of so few complicated apparatus as possible.

For the adaptation between the rate of revolutions of the turbine and generator a gear is necessary in most cases. Here we use a gear drive of standard type.

As a closing device use is made of either a flat gate or a throttle valve. The unit is either in a horizontal or a vertical position (see fig. 2). The horizontal shaft turbine is used for low heads where the turbine can be placed above the lower water level without risk of cavitation. In cases of higher heads the vertical shaft type is used and the turbine lies below the lower water level.

The unit is started by slowly opening the gate (or the valve). When the turbine has attained a nearly synchronous rate of revolutions the generator breaker links up the unit to the network. The gate is then fully opened and the turbine attains a super-synchronous rate of revolutions and supplies full power. When the water level in the power station water storage has fallen to its lower limit the gate closes. The generator breaker switches off when the output is nearly zero. When the water level reaches its upper limit the unit starts up again. All this takes place automatically.

The unit is fitted with electrical protective devices of standard type for overvoltage, overcurrent, reverse power, a divice against switching on to the network when it is dead and a neutral point voltage protection. To protect the unit against overspeeding when the network is dead and in the case of breaker disconnection the unit is fitted with double overspeeding protection, one electronic and one mechanical.

In order to obtain practical experience of the construction, operation and economics of the types of units described above, six prototype plants were built in various places in Sweden in 1975–77. They have now been in operation for rather more than two years. From the technical point of view the experiences gained have mainly been positive. However, in order to satisfy the demand for turbine units suitable for plants which must adjust to the prevalent flow, a study is being undertaken at present of two prototype units with flexible runner blades but without guide vane regulation.

The fields of application in which the various types can come into question may be seen in the following summary:

Units with fixed runner blades

The plants are operated with nominal capacity during the draining of the storage upstream. They are shut off during the re-filling of the storage.

a) Heads of less than approximately 6 m. Connection of turbine casing with throttle valve to open turbine sump or assembly in open turbine sump with flat gate at intake.

b) Heads of more than 6 m. Closed turbine casing with throttle valve. Vertical positioning.

Units with movable runner blades (no guide vane regulation)

With respect to outside interests the plants cannot be operated intermittently but must be driven with regulation for constant upstream water level.

a) Heads of less than approximately 6 m. Connection of turbine casing with throttle valve to open turbine sump or positioning in turbine sump with flat gate at intake.

b) Heads of more than approximately 6 m. Closed turbine casing with throttle valve. Vertical positioning.

Economic Aspects

The construction of the prototype units indicates that it is often difficult, despite the simplifications we have applied, to reduce costs to a point where we can speak of commercial profitability. The costs of the prototypes varied from 2750 to 10 700 SKr/kW. If a large number of mini power stations should be designed, some kind of government support would be required for the less profitable projects. Such suppport is currently being granted. With effect from 1978-07-01 owners of mini power stations are entitled to a government grant amounting to a maximum of 35 % of the cost of the plant. One condition for entitlement to a grant is proof that the project is profitable from the national economic point of view. We estimate that about 100 plants will be constructed during the next few years.

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