# Shortening of the assembly time for small hydro power plants

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***Abstract—*** The vast majority of the best locations for building big hydro power plants, especially in Europe, have been utilized in the previous century. Also the environmental policy of European countries has become stricter. These facts, together with the financial burden of mega projects in hydro power business made an investments into small and micro hydro power plants a viable option. Since each day a power plant is not running produces a noticeable loss in the power output which consequently results into a financial loss, each action, that can make a power plant feed the electricity into the grid sooner is highly valued. To ensure a faster assembly time a series of work sheets have been developed, these shall make the turbine assembly faster, downtimes shorter and the whole process more efficient.

***Keywords —*** assembly time, efficiency, hydro power, hydro power plant, small hydro.

## I. Introduction

Hydroelectric power provides almost one-fifth of the world's electricity. Hydropower is also the cheapest way to generate electricity today. That is because once a dam has been built and the equipment installed, the energy source - flowing water - is free. It is also a clean fuel source that is renewable yearly by snow and rainfall [1]. In EU hydro power was the biggest source of renewable energy in 2011 with a share of 46 %, followed by wind power (26.5 %) and biomass (19.7 %) [2].

The Renewables Directive creates an overall target of 20% renewables across EU in all energy sectors by 2020; it takes a broader approach by integrating the power sector, transport, and heating and cooling [3].

Texas Renewable Energy Industries Association (TREIA) defines the renewable energy as “any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources." [4]

Environmental protection agency (EPA) defines renewable energy as “electric energy generated from solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), geothermal, municipal solid waste, or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project” [5]

The biggest contributor to the renewable electrical energy production is hydropower, followed by wind power and biomass.

Hydropower is based on a simple principle process: taking advantage of the kinetic energy and pressure freed by falling water of rivers, canals, streams and water networks. The rushing water drives a turbine, which converts the water’s pressure and motion into mechanical energy, converted into electricity by a generator. [6]

## II. Current renewable energy situation in the world

Global wind power installed capacity at the end of the year 2000 was only 18GW. That however has changed over the past years. At the end of the year 2012 the installed capacity worldwide was 238 GW. This grow happened with an average rate of more than 25%.

Solar photovoltaic (PV) installed capacity worldwide at the end of the year 2000 was 1.5 GW. At the year 2011 it was approximately 67 GW. And this number keeps growing. The estimation is that at the end of the year 2013 this number will be around 120 GW.

Hydro power has been one of the most explored sources of renewable energy. Even though it still continues its steady growth. While in the end of the year 2000 the installed power of Hydroelectric - run of the river plants combined with Hydroelectric – pumped storage was around 800 GW, at the end of the year 2010 it was around 1050 GW.[7]

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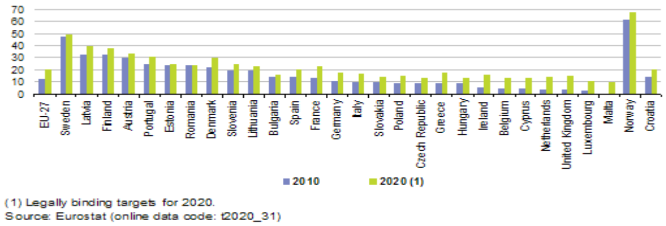
## III. CURRENT RENEWABLE ENERGY SITUATION IN SLOVAKIA

As mentioned in the in introduction, every member of the EU committed to cover a certain percent of its country energy demand by the year 2020. The values of the renewable production in 2010 and planned renewable energy share in 2020 can be seen in Fig. 1 [8]




In terms of its national strategy, Slovakia's target for

Fig. 1 Renewable production planed in EU countries in 2020

exploiting renewable sources of energy is to achieve a 14-percent share of all primary sources of energy consumed by 2020. Based on data by the Economy Ministry, the current share of renewable energy sources is above 11 percent, up from 6.7 percent in 2005 [9].

According the International Renewable Energy Agency (IRENA) the electricity use per capita for the year 2010 in Slovakia was 5164 kWh. The EU consumption per capita was 6285 kWh. While the world consumption per capita was 2863 kWh [10].

That implies that around 568 kWh per inhabitant was produced by a renewable source of energy.

And since around 20.4 % of renewables in Slovakia are produced by hydro [11], approximately 115 kWh was produced by hydropower plants

First it is necessary to analyse the electricity production from renewables (years 2009 and 2010):

Tab. 1 Electricity production in Slovakia (2009 and 2010)

| Type | 2009 | | 2010 | |
|---|---|---|---|---|
| | MW | GWh | MW | GWh |
| Run-of-the-river plants: | | | | |
| < 1 MW | 26 | 75 | 26 | 75 |
| 1 MW - 10 MW | 63 | 181 | 66 | 190 |
| > 10 MW | 1508 | 4344 | 1508 | 4347 |
| Pumped storage | 916 | 236 | 916 | 394 |
| Geothermal | 0 | 0 | 0 | 0 |
| Solar: (PV cells) | 0 | 0 | 186 | 11 |
| Wind | 3 | 6 | 3 | 6 |
| Biomass: | | | | |
| Solid biomass | 160 | 515 | 169 | 636 |
| Biogass | 4 | 22 | 9 | 32 |
| Liquid biomass | 0 | 0 | 0 | 0 |
| SUM | 2680 | 5379 | 2883 | 5691 |

Next table shows the potential of usage of different kinds of renewables:

| Energy type | Technically utilizable potential [GWh] |
|---|---|
| Geothermal energy | 6300 |
| Wind energy | 605 |
| Solar energy | 5200 |
| Small hydro | 1034 |
| Large hydro > 10 MW | 5573 |
| Biogas | 2500 |
| Biomass | 11237 |
| Sum (w/o large Hydro) | 26876 |
| **Sum** | **32449** |

Tab. 2 Potential usage of renewables in Slovakia

When considering the utilization of renewables only for electricity production, a reasonable estimate is 4506 GWh without large hydro, or 10 079 GWh with large hydro.[11]

## IV. HYDROPOWER ENERGY POTENTIAL IN SLOVAKIA

At the beginning of this chapter we have to shortly describe three basic terms, while talking about the energy potential of the rivers.

Theoretical hydropower potential - is the sum of the theoretical hydropower potentials of all the rivers in a country. It is computed from average flows through a monitored sections of rivers, from a total head difference and while having 100% of energy transformation efficiency. The total hydro energetic potential in Slovakia is 13682 GWh/year[12].

Technical hydropower potential – it is always smaller than the theoretical potential because of sections of rivers that are technically not possible or not viable to utilize. Furthermore we also calculate with the efficiency while energy transformation from kinetic energy of the flowing water to the torque on the shaft. This efficiency is around 85%. The value of the technical hydropower potential in Slovakia is around 6700 GWh/year on 625 river profiles. These were picked using a 3D mathematical water level model of the rivers , so in case of their utilization they would not affect each other hydraulically.[13]

Ecological hydropower potential – Ecological potential further decreases the technical hydropower potential , since certain parts of the river profile is not possible to be utilized because of environmental issues. It also counts with the spillway section and fish pass section that decreases the flow going through the turbine and therefore cannot be utilized. [14]

The currently utilized technical hydropower potential is – 4575 GWh / year

The technical hydropower potential that is able to be used – 2125 GWh / year

Hydropower plants according the size can be divided into three main groups:

Large hydro - with the installed capacity > 10 MW
Small hydro – installed capacity from 0.1 to 10 MW
Micro hydro – installed capacity < 0.1 MW

It is however worth mentioning that these values may vary from country to country. For example Germany classifies large

hydro from 5 MW, Italy from 3 MW, but India and China has large hydro only from 25 MW and Brazil from 30 MW.
The following table shows the theoretical hydropower potential in comparison with the technical hydropower potential[11]:

| River | Tot. theor. Hydropower potential [GWh/y] | Tech. hydropower potential [GWh/year] |
|---|---|---|
| Morava | 113 | 29 |
| Dunaj | 3394 | 2511 |
| Váh, Malý Dunaj | 5953 | 2985 |
| Nitra | 320 | 72 |
| Hron | 1406 | 427 |
| Ipeľ | 157 | 34 |
| Slaná | 314 | 96 |
| Bodva | 65 | 3 |
| Hornád | 807 | 262 |
| Bodrog | 692 | 138 |
| Poprad a Dunajec | 461 | 143 |
| Sum SR | 13682 | 6700 |

Tab. 3 Theoretical hydropower potential vs. technical hydropower potential

Another term to describe is the capacity factor of a hydropower plant. The power of a power plant can be computed as follows:

$$P = Q * H * \rho * g * \mu$$

P – Power is in watts,
Q – Flow in $m^3$ / s,
H – Head in m,
ρ - Water density in kg / m3,
g - Acceleration due to gravity
μ - Coefficient of efficiency ranging from 0 to 1
(usually the bigger the turbine the closer to 1)

The capacity factor of a power plant then can be computed using following formula:

$$CF = \frac{P_{generated}}{P_{*365*24}} * 100$$

$P_{generated}$ – Power generated over the year in MWh
P – Installed power in MWh
CF – capacity factor in %

## V. The Growing Importance of Small Hydro

Slovak climatic and hydrological conditions are compatible with expanded reliance on hydro power. Large hydro denotes to a huge portion of whole hydropower output as seen on the following graph [11].

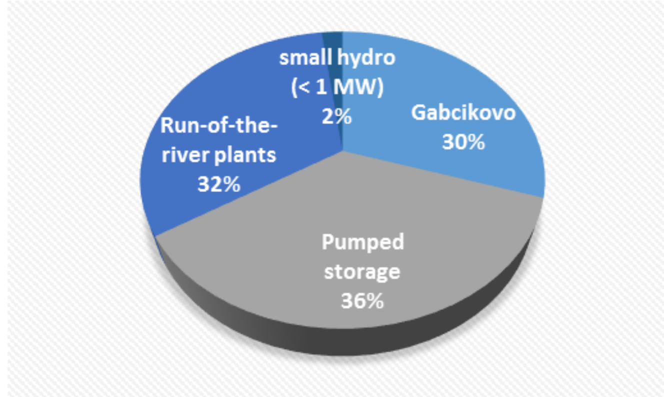



Fig. 2 Share of different types of hydropower plants in Slovakia

The largest hydro power plant, which is located in Gabcikovo, has an installed capacity of 720 MW and generates almost third of Slovakia's renewable electricity.
Slovakia's hydro power stations, which date back to the 19th century, also provide flood control services, as well as water for irrigated agriculture and industry; they also promote water transit by regulating stream flow.

However, construction of additional large hydro power stations now seems unlikely, due both to environmental concerns and to the high costs of providing under-served rural and mountainous communities with additional electricity supplies via the construction of large dams.
In these circumstances, the construction of additional small hydro stations could be a more cost effect and less environmentally intrusive solution.
More than 190 small hydro plants are currently in operation in Slovakia; their growing commercial viability in recent years has made possible reductions in feed-in tariff rates. The construction of additional small hydro plants by Slovakia's electricity generation company (and owner of large hydro power stations, Slovak Power Stations), is therefore anticipated—particularly in the Váh river basin.[15]

## VI. Assembly Time Made Shorter

Because of these facts, the demand for small hydro power plants has been increasing in last few years. Companies producing turbine equipment need to react to the demand faster and organize the manufacture better than before. The rise in the manufacturing requires also an increase in manpower.
Manufacture and assembly of turbines however is a process that requires both technical thinking and skills. Hiring employees to the manufacture that have skills with turbine equipment is not an easy task, and employers often have to go below the set requirements just to get the labour force.
Therefore a set of – so called "part sheets" have been developed to make the work easier to the new hires (and also to the skilled workers) and ensure the high quality of the assembly process. Since turbine manufacturing is in no meaning a serial manufacturing, but each piece is a "prototype" these part sheets will vary from project to project,

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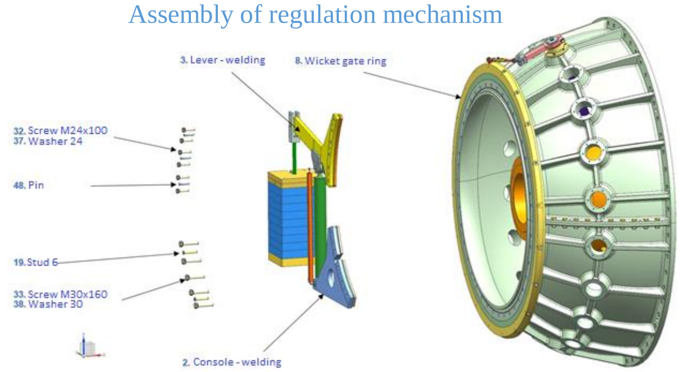
but the principle and template remain the same, to ensure a kind of standard.

These part sheets are also supposed to make the logistics simpler and more accurate. As each of the part sheets is showing all the required components, those can be brought in one package to the place where they are supposed to be assembled. That way all the required components should be on the spot for the employee to work with. That not only reduces errors, but also decreases assembly time, since the worker has all the required components next to him and does not have to look for them around the manufacture.

## VII. PART SHEET EXAMPLE

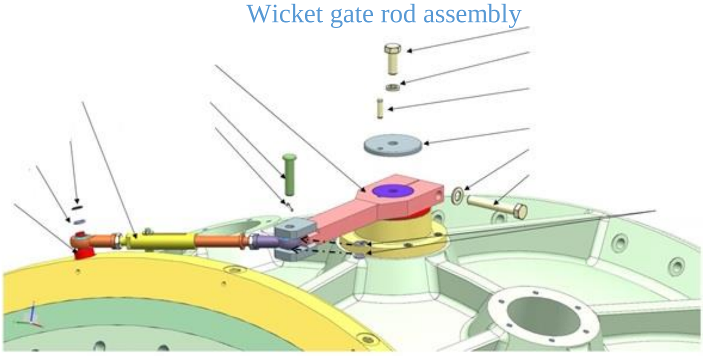
Assembly of regulation mechanism



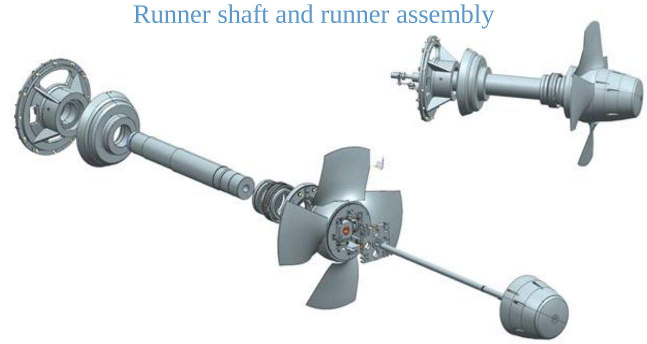

| N. | ITEM | N. | TYPE |
|---|---|---|---|
| 2. | Welding construction - Console STM-09-0900041/1 | 1 | PZ |
| 3. | Welding construction - Lever 09-0900042 | 1 | PZ |
| 8. | Wicket gate ring 09-0800011 | 1 | PZ |
| 19. | Stud 6 STM-09-0800024/1 | 2 | STD |
| 32. | Screw M24x100 DIN 931 8.8 Zn | 6 | STD |
| 33. | Screw M30x160 DIN 931 8.8 Zn | 5 | STD |
| 37. | Washer 24 DIN 7980 Zn | 6 | STD |
| 38. | Washer 30 DIN 7980 Zn | 5 | STD |
| 48. | Pin 20x100 DIN 7978 | 3 | STD |

To retain this article in a reasonable length, only two more visualization from the part sheets developed this way, without the bill of materials, are going to be shown:

Wicket gate rod assembly



Runner shaft and runner assembly



## VIII. CONCLUSION AND FURTHER RESEARCH

The usage of first six of these work sheets has been launched several months ago. Significant time savings have been observed using mainly work sheets where more complicated assembly parts are shown (wicket gate rod, runner, etc.).

The next stage will be aimed to quantify all the impacts of these work sheets. Time savings need to be quantified, and the part sheets, with small changes, need to be used in different projects to evaluate their versatility.

These part sheets shall be useful in three departments. In project management department to have a „big picture“ while assembly period is in progress. In the logistics department while planning the material flow. And most importantly in the manufacture, where these should contribute to shorter assembly time, less error rate and decreasing the downtimes.

These part sheets also play an important role in the company know-how, since each improvement in assembly, whether it is a reduction in material used, or reduction of components that leads to the same or a better performance is registered in a part sheet and leads to part sheet improvement. Therefore the next project can be done in the same or improved quality. In this case even the loss of a skilled labour force, does not necessarily mean the loss of know-how.

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