Introduction of Renewable Energy into City-Chino in Nagano.

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1. Introduction

City-Chino is located almost at the center of Prefecture Nagano, which is also nearly at the center of Japan. Area of Chino covers altitude ranging from 750 to 2899m, while inhabiting area is mainly 750 to 1,200 m. Population is about 55,000, while roughly three million people visit Tateshina highland and other resort spots for relaxation and recreation. Average temperature over a year is 10.8 deg C (cf. 16.2 deg C in Tokyo), and annual precipitation is 1,200 mm (cf. 1,800 mm in Tokyo), which offers comfortable inhabitant environment. The sunshine hours are long, the land is rich of water, and about 75 % of the area is covered by forest. These are all advantageous conditions for the introduction of the renewable energy.

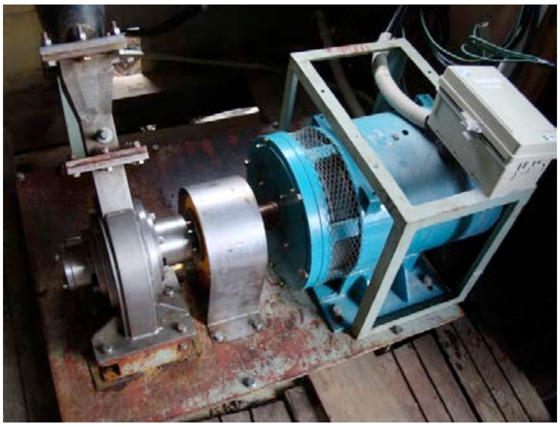

Fig. 2 Hydroturbine (cross flow type) and generator (6 kW max.)

Introduction of the renewable energy is now highly promoted in Japan because of the global warming and the disastrous experience of the Tohoku earthquake and tsunami. FiT (Feed-in Tariff) has been started from 2012 in Japan. City Chino started a new section, Natural Energy Section, in the Department of Industry and Economy to accelerate the introduction of the renewable energy and thus to promote local industry and economy. The first author is now with the Natural Energy Section and is engaged in promoting the utilization of the renewable energy in the administration of the local government.

2. Activity of introducing renewable energy in City Chino

2.1 Activities by private sector

(1) Natsusawa mineral spa

A mountain lodge is operated by private sector to serve hikers and climbers of mountain Yatsugatake (Fig. 1). Since it is located remotely from the city area, no commercial transmission line is connected. Thus, the renewable energy is intensively utilized. The energy is 100 % supplied with the renewable energies such as small hydro, solar, wind and biomass power. Especially, a small hydroturbine of the cross flow type (Fig. 2) is installed and connected to a water pipe with water head of about 30 m since 2001. The electricity of 6 kW max is generated constantly for all year around including the winter time. Now almost all the electricity is supplied by this hydro system. City office is now going to promote this activity with use of the website and through new souvenir products.

Fig. 1 Natsusawa mountain lodge at 2,000m. Solar panels and small wind turbines are seen.

(2) Onsite test of a small hydroturbine of washbasin type

An onsite test is now being made using an agricultural water channel in Chino. As seen in Fig. 3, water is eccentrically introduced into a basin and the water vortex is generated, which rotates an impeller. This type is suitable for a small head difference and easy to be installed without large civil work. Another feature is that the leaves and debris flow easily through the basin and no filters nor screens are needed in front of the intake. This test is operated by a company AEC Co, Ltd. in Chino. This is the first onsite test of this type in Japan. It is planned to run for three months and its commercial supply is expected after the test.

(3) Hydropower station by a private company
A hydro power station of 250 kW is now being operated by Mibugawa Power Company Co, Ltd. This type of small power station is usually installed by utilizing a level difference of U-turning agricultural water channel. Chino is located in the slope of Mount Yatsugatake; there are not few spots suitable to this type of installation. Other two stations are going to start operation in 2013.

Fig. 3 On site test of a washbasin type hydropower generation (200 W max.)

(4) Small solarpower station by private person
Since the start of FiT in 2012, a private person is now able to install a solar power station and sell the electricity to power company. Capacity is typically 50 to 150 kW in this area. Now two sites are operating and other three are in preparation. Figure 4 shows an example of such a solar power station with 50 kW. From the aspect of the land use, the agricultural land must be converted to miscellaneous usage, which must be admitted by the local government. The land tax increases, but it can usually be compensated by the income. So-called Mega-Solar power station usually requires a large land and big civil work, but a small solar power station needs no such large investment at the beginning. So, the city government is now promoting this type of small solar power stations.

2.2 Activities by local government Chino
(1)Promotion of renewable energy by subsidy Smaller solar power facilities, installed on the roof of private houses, are promoted by subsidy. City Chino offers 200,000 yen (max.) for the solar power facility less than 10 kW since 2003. To facilitate the biomass utilization, 100,000 yen (max.) is offered for a pellet stove. More than 200 applications are made for the solar power and 10 for the pellet stove. The planned budget is consumed in a short period every year. This indicates citizens have large interest in the renewable energy.

Fig. 4 Privately operated solar power station. The electricity is sold to the utility company.

(2) Research committee on Future Eco City Chino

As mentioned before, the City office Chino started Natural Energy Section in the department of Industry and Economy and also organizes Research committee on Future Eco City Chino in collaboration with private companies, NPO's, and a university, Suwa Tokyo University of Science. Interested and active citizens are also included. Four sub-committees are running.

1) Solar power sub-committee

Since the start of the FiT, Mega Solar business is now widely being developed in the whole country by large enterprises. In these cases, most of earned profit often flows outside of the local area and only a small portion such as the rent of ground and cost of maintenance work remains there. The sub-committee studies a framework in which earned money remains in the local region and is recirculated to further promote local industry and employment. A local company is now established to realize this scheme. A solar power station with about 2 MW is now going to be constructed on a field of Yatsugatake Agricultural Vocational School. In this neighboring area, there exist several water supply facilities, suitable for small hydro power generation, and a compost center, usable for biomass energy production. Accordingly, this area is now going to be developed in combination as Chino Eco-Energy Park. Figure 5 indicates this area.

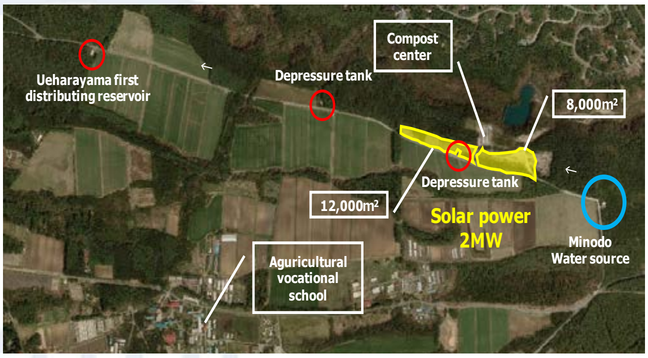

Fig. 5 Area of Chino Eco-Energy Park including solar, small-hydro and biomass energy generations

A low-cost solar-powered street light has been developed by collaboration of small companies and citizens in Chino. It can be produced now with a less than half of normal market price, because design and assembling are made by themselves. Now 13 units have been installed in primary and middle schools in Chino and 26 are planned to be constructed in future. This is expected to help the eco-education of children.

2) Small hydropower sub-committee

Special feature of the city water supply of Chino is that all the water sources are underground fountains and no river water intake is utilized. Accordingly the water supply is stable independently of season. On the other hand, the water flow from individual source is rather small but experiences a large elevation difference before delivered to the final consumer. Now, installation of a small hydropower generator in this water supply system is studied by the sub-committee. Technical feature of this flow is a relatively small flowrate compared to a large elevation difference. Fairly intensive search was made, but no hydroturbine suitable for these conditions has been found with a reasonable price. Accordingly, a pump reverse turbine is now being developed in collaboration with a pump manufacturing company, Komatsu Pump Works Co, Ltd., in a neighboring town. After a model test with an equivalent specific speed, suitable type and size will be selected and be installed at one of the depressurize tanks shown in Fig. 5.

The area of city Chino spreads over the foot of Mount. Yatsugatake. A network of agricultural water channel is well developed even since 250 years ago. There are also many branches of Tenryu River system. These water channels and rivers are all regulated by the river law and their stake holders. Since the regulations on the 1st and 2nd class rivers are strict, normal class rivers are now investigated. Those whose cost can balance with income will better be operated by private sectors, while those cannot will be promoted by the city government if beneficial with aspects of education or industry promotion.

Fig. 6 An agricultural water channel (top) and a water fall (bottom), at which a small hydropower station is planned.

3) Utilization of unused energy sub-committee
Since the 75 % of the city area is covered with the forest, thinning of the forest and the utilization of the resultant timber are of great importance both from the preservation of the forest and also from the promotion of the renewable energy. The city office supports the pellet stove as mentioned earlier. A private sector develops a wood stove suitable for a kind of wood common in this region. The developed stove becomes fairly popular in this area. The sub-committee gives advices in the occasions of construction or renovation of public facilities to introduce renewable energies.

3. Laboratory test of a microhydroturbine
Although large scale hydroturbines are well developed and their technical characteristics are studied in detail, those of microturbines are not known well. Thus, a laboratory scale performance test of a microhydroturbine is being carried out. It is a turgo type impulse turbine made by a Canadian company Energy Systems & Design [1]. The inlet water passes through one or two small nozzle(s), where the pressure head is converted velocity. The water then impinges to the turbine runner, which converts the momentum energy of the water into shaft power and spins the generator. In the generator, magnets are imbedded in the rotor that moves past coils of wire, where the electricity is generated. This electric power is first the alternating current (AC), and then is

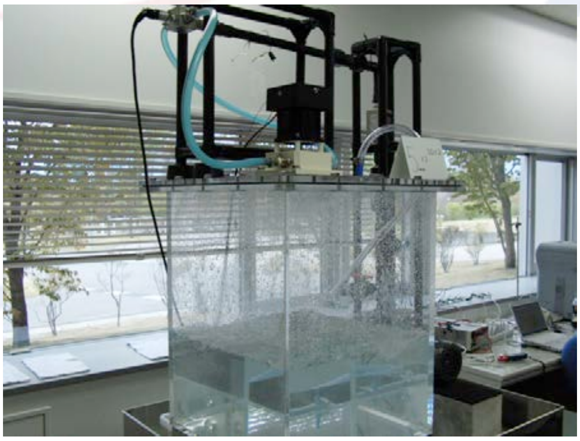

Fig. 7 Outlook of the test loop. The microhydroturbine is seen at top center, the pump bottom right, pressure gauge top left.

inverted into the direct current (DC) with a rectifier. The generator was directly coupled to the turbine (see Fig. 7).

A small water loop was constructed to circulate water. The water is circulated by a small pump. The flow rate and the water head was measured and fed to the water turbine. A photograph of the circulation loop is shown in Fig. 8. The hydroturbine is installed on the top of a reservoir tank. After driving the turbine, the water was poured into the tank and recirculated by the pump. Diagram of the test loop and the arrangement of apparatus are shown in Fig. 9. Both the flow rate and the pump head changed following the performance curve of the circulation pump and the opening of the regulation valve.

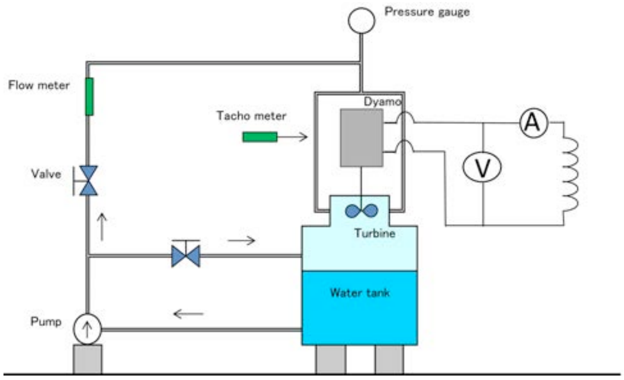

Fig. 8 Diagram of the test loop and measurement devices.

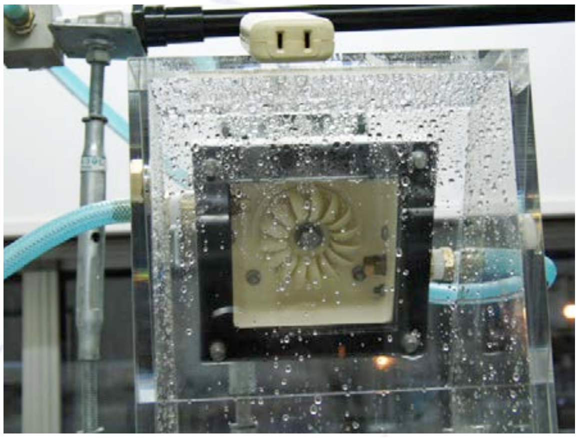

Fig. 9 Impeller and nozzles

The tested turgo impeller of 75mm in diameter is shown in Fig. 10. Two water nozzles are seen in the photo. The nozzle head is replaceable for diameters from *d*=3 to 7 mm depending on the flow condition. In the present test, one and two nozzles were examined. The water head and the flow rate were adjusted by a flow regulation valve. The rotation speed *n* of the turbine was measured with use of a non-contact tachometer.

To measure the generated electric power, ohmic resistance was connected to the output terminals. The voltage *V* and the current *I* were measured to obtain the generated power. In the measurement, the electric load was changed by adding the ohmic resistance in parallel, that is, by increasing the conductance (1/Ω).

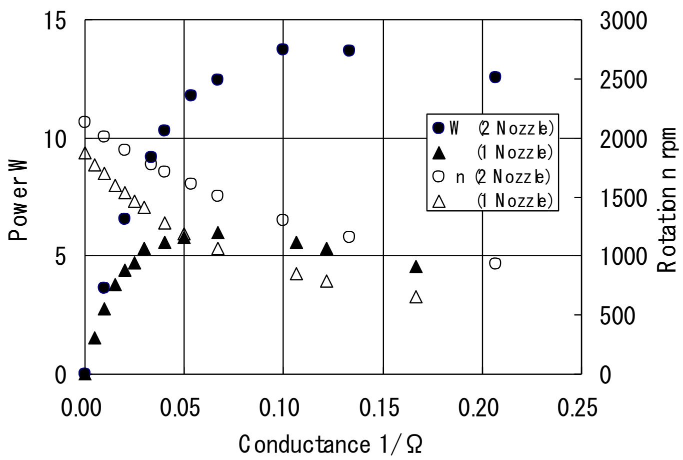

Fig. 10 Generated power P (W) and the rotation speed n (rpm) for one and two nozzles with d=7 mm. Pump head was mostly constant as 90- 104 kPa.

Typical results are shown in Fig. 10, where the generated power and the rotation speed are given for single and two nozzles with d=7mm. With the increasing conductance, that is, the decreasing ohmic resistance, the power increases and the rotation speed decreases. A maximum power appears at a conductance depending on the flow and nozzle conditions. The maximum power is of course larger in the two nozzle system than in the single one and is more than doubled.

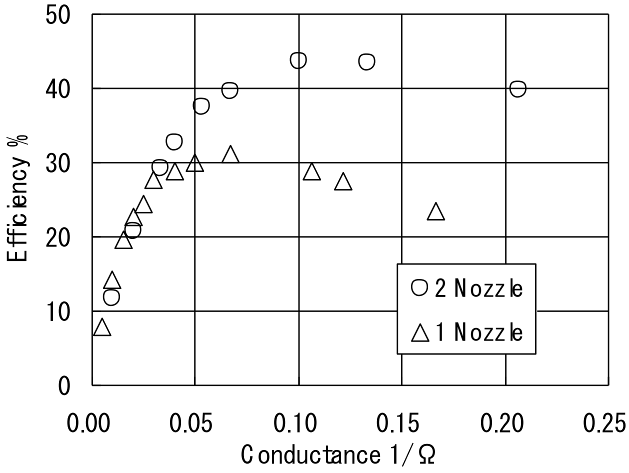

Fig. 11 Efficiency for one and two nozzles with d=7 mm. Pump head was mostly constant as 90-104 kPa.

To compare these two cases, the efficiency is plotted as a function of the conductance in Fig. 11. The measured power in the present method was not exactly equal to the power generated by the turbine, because the power loss inside the generator was not included in the measured value. To account the loss due to the internal resistance of the generator, the open circuit voltage (V_0) was measured prior to the experiment as a function of the rotation speed n. The obtained voltage was used instead of the one between output terminals to calcuated the generated power including the loss due to the internal resistance. The difference was small and within several percents. Thus, the output power P is defined as $P=V_0I$. However, since there still exist core and mechanical losses, the net generated power and the efficiency are higher than those obtained by the present methods.

The theoretical hydrodynamic power P_{th} at the exit of the nozzle(s) is the product of the momentum energy and the flow rate Q; that is, $P_{th} = (1/2)\rho v^2 Q$, where ρ is the density of the water, and v the velocity at the nozzle outlet. The velocity can be obtained as $v=Q/\pi(d/2)^2$, where Q is the flow rate at *each* nozzle. Then the efficiency η is defined as $\eta = P/P_{th}$. Figure 11 gives the efficiency obtained for one and two nozzles with d=7 mm. The efficiency is almost equal for one and two nozzles when the conductance is small, while that of two nozzles extends up to a larger value with the increasing conductance.

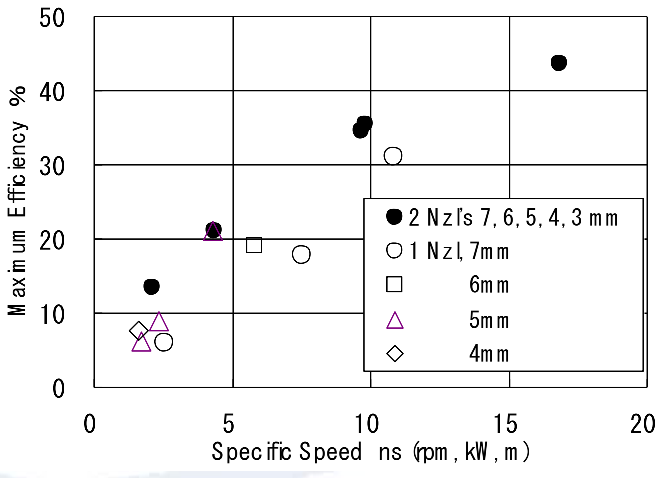

Fig. 12 Maximum efficiency for one and two nozzles versus the specific speed.

Figure 12 shows the maximum efficiency against the specific speed n_s of the hydroturbine for one and two nozzles with various nozzle diameters. The specific speed n_s is defined as $n_s=nP^{1/2}/H^{5/4}$, where H is the equivalent water head in meter calculated from the water velocity at the nozzle exit. The maximum efficiency increases with the increasing specific speed and is higher for the two nozzles than for the single one. The maximum efficiency reaches up to 45 %, which is fairly high for such a small system.

4. Concluding remarks

The City Chino is a town rich in various renewable energies such as the solar, hydro and biomass. However, their utilization is still at the beginning stage. On the other hand, the interest in the renewable energy is increasing very rapidly among industries and citizens. The city government of Chino intends to enhance their utilization in order to preserve environment and also to promote social and industry activities.

A series of performance test was made for a microhydroturbine. A simple test method was established to measure the generated power and the efficiency with a reasonable accuracy. A microhydroturbine with one and two nozzles were tested and compared for various nozzle diameters. A fairly high efficiency was obtained for such a small hydroturbine.

5. Reference

[1] The Watter Buddy, Owner’s manual, Energy Systems and Design, Sussex, Canada. (2012).

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