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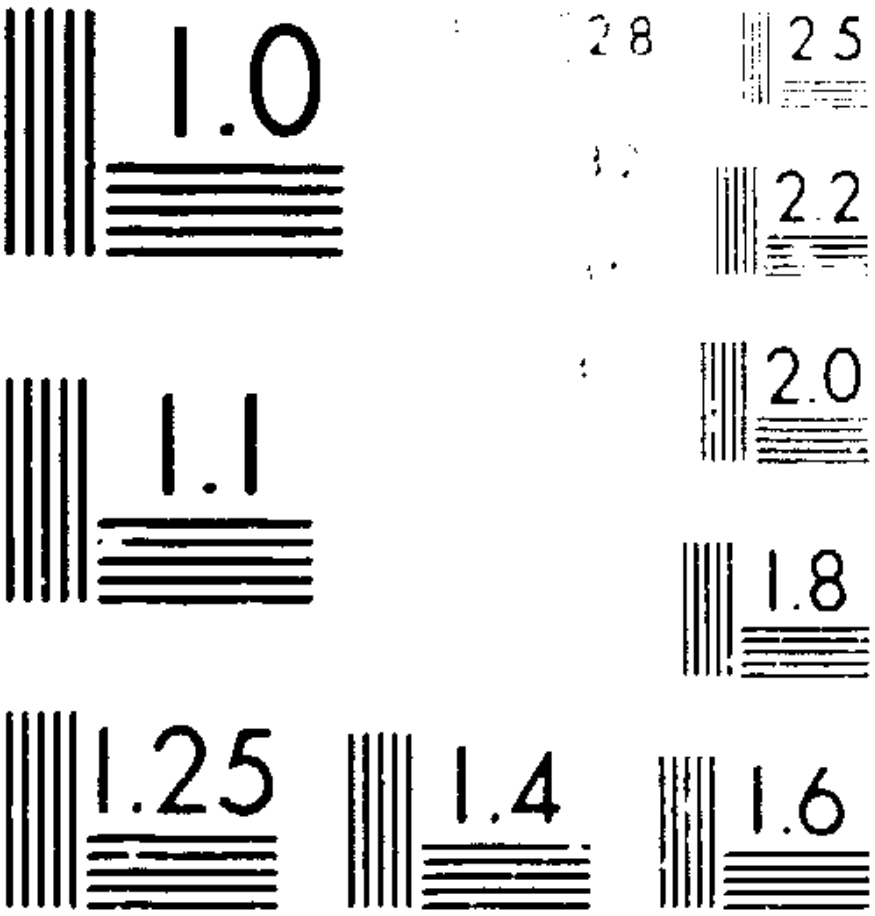
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YUGOSLAV EXPERIENCES, ACHIEVEMENTS AND POSSIBILITIES OF CO-OPERATION WITH DEVELOPING COUNTRIES IN THE AREA OF MINI-HYDROELECTRIC GENERATION UNITS*

by

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Introduction

Decentralization of power generation is nowadays generally accepted as a potential and expedient way of developing energy resources to meet integrated rural requirements, as well as to support projects and programmes for small-scale rural industrialization in developing countries. Past efforts at achieving these objectives through the expansion of centralized national distribution grids seem not to have always achieved the desired results. In addition to this, the growing shortage of energy sources has become the most serious limiting factor of development in recent years. The plight of the developing countries is particularly bad, because they can hardly catch up with the continuing rise in oil prices, while possessing only small known reserves of coal and/or other energy resources.

As most of the developing countries have rich and hitherto often not fully exploited hydrological resources such as streams and rivers, brooks, rivulets, waterfalls, etc., it is felt that these sources could be profitably exploited by setting up decentralized mini hydro-generation (MHG) plants. There exist various definitions and criteria regarding such plants, but the most common classification is as follows:

(1) micro hydro-power-stations .... up to 100 kW
(2) mini hydro-power-stations..... 100 - 1000 kW.

By now a number of developing countries have set up such facilities and have thus been able to extend the benefits of modern technology to rural areas, cut down their growing energy expenses, and derive other socio-economic benefits. A number of other developing countries have long-term plans to establish MHG facilities and are taking

effective steps in this direction. There is yet a third category of countries which, although they possess the necessary potential, have not yet considered, or have been unable, to develop their resources because they lack the requisite technical capabilities and/or require external assistance in this regard. This is why there seems to be a great need for strengthening co-operation among developing countries, for an exchange of experience, and for technology transfer in the area of mini hydro-generation, as emphasized by the Declaration adopted at the UNIDO/ESCAP Seminar-Workshop on this topic held in Kathmandu (Nepal) in Sepbember, 1979.

It is along these lines that the present paper discusses Yugoslav experience and achievements as well as possibilities of co-operation with other developing countries.

Yugoslav Approach to MHG: Socio-Economic Background

The latest survey of the structure of completed hydro-electric power-stations in Yugoslavia published in December 1979 does not list separately facilities with an output of 1 MW or less, but only records that hydro-electric power-stations of up to 10 MW have a total output of 140 MW and that, according to technical and economic estimates, further construction of power-stations of this type would make it possible to include into production still unexploited hydro-potentials of a total output of 336.8 MW.

In the total output of Yugoslav hydro-electric generation facilities, and even in the total still unexploited hydro-potential this accounts for a very small percentage. However, since minor streams, brooks, waterfalls etc., mostly situated in mountainous regions, are hydrologically practically uninvestigated and technically not yet defined, the indicated 336.8 MW of non-utilized potentials should be understood as the most restrictive estimate, which might be greatly multiplied through the

investigation of minor flowing waters, so that their share in estimates of the country's total, still unexploited hydro-potentials would greatly increase. This becomes the more important if the fact is considered that because of the high degree of exploitation of hydro-power potentials suitable for the construction of major power projects, Yugoslavia will be forced during the next medium-term period to concentrate on the erection of medium-power plants (mostly those between 10 and 50, or 50 and 100 kW). In the light of this it is obvious that the Yugoslav power generating industry and other interested social factors will soon see the importance of MHG in an entirely new light.

However, the high degree of exploitation of hydro-power potentials suitable for the installation of major power plants is only one of the factors which, in Yugoslav conditions, impose the need for wider investigations and a speedier development of small hydro-electric power-stations.

- The second important reason is the continuing rise in prices of imported oil, following the oil crisis in the mid-197os which inflicted a heavy burden on Yugoslavia's balance of payments, the country being a net importer of energy. For illustration let us add that Yugoslavia's net import of primary and secondary energy during the 1975/198o period has been increasing at an average annual rate of 11.8 per cent, so that this year it is expected to total 747.47 units expressed in 10^{15} joules, or about 41.3% of the country's total energy consumption this year.

- Finally, the third important reason for giving priority to the development and erection of small hydro-electric power plants in Yugoslavia is the fact that the country's existing integrated electrical power system and distribution network are designed primarily for peace-time utilization, their infrastructure containing too many vulnerable points to make them fully reliable in war conditions.

This is why the country, bearing in mind the long-term contradictions inherent in international relations. and the armed conflicts spreading throughout the world, has been paying due attention to increasing its defence capacities, the respective conclusions being that the existing power system and distribution network must be accompanied by a parallel, highly decentralized network of power generating facilities for use in case of war, so that demaged or destroyed facilities of the existing power system could be replaced and/or replenished. This programme gives an important place to small and MHG units. Installed on rivulets, brooks and waterfalls in remote mountain areas, they would be less visible and out of easy reach of an aggressor, and serve the purpose of total national defence the strongholds of which would be situated in the country's mountain regions anyway.

Institutional Framework: Problems and Prospects

The Socialist Federal Republic of Yugoslavia consists of six republics and two autonomous provinces. Its socio-economic system is based on freely associated labour and on the system of self-management by the working people in all spheres of public affairs.

Being a community of voluntarily united peoples and their republics and autonomous provinces, the Federation safeguards only the fundamental common interests such as national freedom and defence, territorial integrity and sovereignty, the system of socio-economic relations, and the foundations of the country's political system, while all other common interests, primarily those in the spheres of economic and social development are fulfilled through various forms of self-management co-operation and agreement between the individual republics and provinces.

Thus Yugoslavia's unified electro-energy system and distribution network rest upon the co-ordinated activities of eight republican and provincial Communities for Electro-

Energy, which are specialized organizations concerned with the planning, financing, production and distribution of energy within their respective territories.

A study of the activities of these Communities will show that differences in economic development between the individual republics and, still more, the special problems of energy supply and different geological and hydrological conditions have produced different levels of interest and experience in the sphere of small-scale hydro-power facilities. To date, the greatest successes in this respect have been achieved where the existing hydro-power potentials s suitable for the installation of medium- and high-power plants have already been more or less exhausted, where no major coal deposits and/or no alternative energy resources are available, or where there exist inhabited but remote mountain regions with abundant, untouched water courses.

In this sense the Socialist Republic of Slovenia offers a percent example.

Covering the area on the south-eastern flank of the European alpine region, this Yugoslav federal republic has almost exhausted all its existing waterfalls suitable for medium and high-power hydro-electric plants, while its coal reserves are rapidly diminishing. However, it possesses considerable hydrological resources in the form of small rivers, streams, brooks, etc. in its remote though fairly populated hilly areas.

In order to lessen its dependence on energy imports from other Yugoslav republics and from abroad, the Slovenian Community for Electro-Energy decided a few years ago to direct part of its efforts and resources towards research and development and the practical introduction of small, mini and micro hydroelectric facilities. For this purpose they have set up a special Business Committee for the construction of small hydroelectric plants which has drawn up a programme under which as many as 100 MHG units are to be erected during the 1981/1985 period. The Community

has also included in the programme interested manufacturers of equipment both from Slovenia ("Litostroj", "Eletrokovinarstvo") and from other republic ("Rade Konačr", Zagreb. "Sever", Subotica, etc.), and organizations for scientific research and project designing (Institute for Turbo-Engineering, Ljubljana, "Elektroprojekt", Ljubljana).

The erection of small and particularly of MHG units is a complex task involving highly varied work ranging from finding, registering and measuring suitable sites, to standardization of equipment and settling of numerous still unsolved systemic, financial and administrative questions.

The institutional system for the erection of small hydro-power units can therefore still not rely exclusively on the activity of central institutions on the republican level or, still less, on the federal level; initiative is also needed on the part of other interested factors, primarily the citizens, i.e. the end users of energy, their local communities, the enterprises in which they work, and organizations which manufacture equipment for this type of hydro-electric power-stations.

In this sense, the Yugoslav socio-economic system, being based on a free association of labour and resources and on the system of self-management, enables working people and citizens to realize to a maximum their own and their common interests within the framework of their enterprises, socio-political communities and organizations, or again as private farmers or craftsmen.

It may perhaps be best to show how this system operates in practice by describing a concrete example.

Case Study of the ~~Tomlin~~ Tolmin Commune

When discussing concrete possibilities for a decentralized decision making system in the sphere of MHG units at the local level, we must turn to an example from

the Socialist Republic of Slovenia, - more precisely, from its largest commune Tolmin.

Situated in the hilly part of West Slovenia, this commune lacks in major rivers but is rich in small streams and mountain brooks fed by Slovenia's heaviest average annual precipitation. This caused the electrification process in the Tolmin commune to proceed at a very slow rate, so that electricity did not reach the last village before 1978. However, even today many isolated farms and hamlets situated high up in the mountains are not supplied with electricity from the central national power system since current economic calculations and possibilities would not justify the erection of transmission lines and transformer substations. For these reasons the inhabitants of the Tolmin commune had to depend on their own supply of electricity which they ensured by installing private aggregates on small rivers and brooks in which their region abounds. Thus on the basis of their own technical designs and skill and using second-hand or even waste materials, or with the assistance of individual experts, they erected private flour-mills, saw-mills and MHG units on mountain brooks, rapids and waterfalls from which they obtained electricity for the requirements of house-holds or/and small-scale industries. At one time, according to current data, more than a hundred such facilities were in operation in the area of the Tolmin commune. However, the electrification of the commune from the central distribution network led to the closure of most of these private power generating facilities since their price and maintenance costs exceeded the cost of electricity from the national grid.

However, in recent years, induced by the general increase in energy prices and the diminished possibilities of employment in the valley, the inhabitants of the Tolmin commune, chiefly farmers and craftsmen, have turned to reconstructing their discused MHG units and setting up new ones.

However, as it turned out, they were hampered in these efforts by a series of difficulties. lack of expert knowledge required for identifying suitable water courses and for measuring the hydrological and technical characteristics of individual micro sites, lack of inexpensive standardized equipment in the market of electrical equipment, and also unsettled legal questions and financial problems. At the initiative of interested citizens, in spring this year a Section for MHG Units was set up with the communal Federation of Organizations for Technical Culture, with the task to study, promote and support the erection of MHG units according to the interests of citizens and also to those of the Tolmin socio-political community in view of its responsibilities and plans connected with the development of the material basis of total national defence.

The first task to be accomplished by the Section was the registering of existing small hydro-power units wihin the area of the commune. An official inquiry in all local communities has shown that 11 MHG units, 6 saw-mills and 4 flour-mills utilizing the power of the Tolmin water courses are currently in operation in the Tolmin area. Of the MHG units one has a capacity of 30 kW, three have 15 kW each, and the rest 12 kW, 9 kW, 8 kW, 6 kW, 3.2 kW and 3 kW, - i.e. a total of 116.2 kW. These MHG units produce a monthly total of 33,664 kWh which, of course, is very little even in relation to the commune's total consumption. However, if it is considered that, in the case of war, monthly consumption per household in envisaged to total 90 kWh, then the existing MHG units in the Tolmin commune alone and on the present low technical level could - in war conditions - supply with electrical energy 836 households or other, similar consumers. The inquiry has further shown that if to the existing facilities were added all the registered disused MHG plants and the sites where once flour-mills, saw-mills or similar facilities were in operation, then the area of the Tolmin commune includes at least 153 micro sites suitable for the erection

of MHG units. Aware of the importance of this fact for meeting the electricity requirements of isolated farms and small-scale industry and also those of total national defence, the Tolmin Communal Assembly, on the basis of the results of the inquiry, has commissioned the Institute for Turbo-Engineering in Ljubljana to work out a study of all available hydro-potentials, prepare hydrological and technical analyses both of the registered and of new micro sites, and determine the optimum types and outputs for future MHG units within the commune's area. Under the same contract, over the next two years the Institute is to construct and set up five MHG units within the Tolmin area, i.e. two micro aggregates for a fall of water of 5 or 15 metres, one mini aggregate adapted to the requirements of total national defence with an output of 50 kW, and two aggregates of 100 kW and a fall of water of up to 100 metres, or of 80 kW with a fall of water of up to 10 metres, designed for connection with the existing distribution grid.

At this point it should be mentioned that the Tolmin Federation of Organizations for Technical Culture is linking its action regarding the development and erection within its area. Accordingly, it has given the initiative for a wide research action to be organized at the level of the Republican Federation of Organizations for Technical Culture in which students, members of school organizations for technical culture, would be engaged on measuring hydrological and other parameters of all suitable water courses in Slovenia in general and in the Tolmin commune in particular. For this purpose a special publication is being prepared which is to contain instructions for measuring the fall and flow of water and all necessary technical parameters and include drawings of MHG units suited to the characteristics of different water courses.

All these initiatives taken at the level of local socio-political communities and organizations, and also of interested individual citizens, require technical knowledge,

expertises and systemic measures which are impossible to provide and put into effect at the local level alone. Therefore in Slovenia, and also in other Yugoslav republics, steps are now being taken effectively to connect the initiatives started in central republican organs and in Communities for Electro-Energy with those in the field. For instance, the question of financing the construction of mini hydro-power-stations for the requirements of isolated farms and small-scale industry in hilly regions is to be solved by means of favourable credits for which the necessary funds are to be provided by the Republican Community for Electro-Energy and by interested manufacturers of equipment, while the construction of facilities for the requirements of total national defence is to be financed from funds specially earmarked for these purposes at all levels, - from the republican to the communal level. As regards scientific research work on the typification and standardization of equipment for mini hydro-electric power-stations, most of the required funds are at present made available by work organizations which manufacture such equipment, while part of the funds is provided by the Republican Communities for Scientific Activities.

As can be seen, the development of small hydro-electric power-stations in Yugoslavia has already made good progress, although the described experiences and achievements show that much work will still have to be done.

Possible Areas of Co-operation with Other Developing Countries

As mentioned before, considerable succes has been achieved and valuable experience gained in Yugoslavia in the development of appropriate technology in the sphere of small and MHG units.

Among the Yugoslav manufacturers of equipment, perhaps the biggest results have been achieved so far by "Litostroj" of Ljubljana. This organization, specializing in the manufacture of Francis, Caplan and Pelton turbines,

automatic speed and discharge governors, turbine inlet valves, lubricating, cooling and draining devices, draft tube gates, head valves, etc., has thirty years of experience in the construction of turbines or hydro-power aggregates. As regards MHG plants, "Litostroj" built and delivered these in greatest numbers during the first years of its activity (1946-1950), to concentrate subsequently - as the socio-economic development of Yugoslavia gathered momentum - on the construction of big turbines and aggregates of up to 150 MW and more.

However, in recent years, due to rising energy prices and the development of the concept and material basis of total national defence, "Litostroj" has again devoted part of its research and production facilities to the manufacture of small and mini turbines, or aggregates, for the generation of electricity. Thus, in addition to supplying domestic buyers, "Litostroj" has supplied equipment for hydro-electric power projects in a number of friendly developing countries such as the Kamburu project in Kenya, Cabra Corral in the Argentine, Ramu I in New Guinea, Kidatu in Tanzania, and the Hemrem Dam project in Iraq.

It should be emphasized here that in keeping with Yugoslavia's policies of non-alignment and of strengthening collective self-reliance of developing countries, Yugoslav organizations do not limit their business operation by strictly commercial criteria but, co-operating with developing countries, also seek to provide technical assistance by investing considerable funds in the research and development of appropriate technologies and into programmes for the training of technical personnel from fellow developing countries.

One of the latest actions of this kind was organized and put into effect by IMGRA, Zagreb on the basis of the Agreement on Technical Co-operation and Assistance concluded between Yugoslavia and Nepal. As part of the full engineering service contracted with several

Yugoslav enterprises, "Litostroj", for instance, had the task to carry out investigation work in the field, determine the most suitable technology, and construct and install two turbines, while "Rade Končar", Zagreb supplied the generators and other equipment for an MHG unit at Silghadi Doti. The task was completed quickly and successfully and the respective unit, equipped with two Francis turbines (of 105 kW capacity each) with horizontal shafts and fully designed, constructed and installed by Yugoslav enterprises and on the basis of Yugoslav technology, has since been operating to the full satisfaction of the Government of Nepal.

As indicated before, apart from "Litostroj" there are several other Yugoslav enterprises which manufacture aggregates for MHG units or certain important components of these aggregates. Especially noteworthy are the achievements of the Electrical Machinery and Equipment Section of the "Uljanik" shipbuilding industry in Pula in the Socialist Republic of Croatia. Though having less experience than "Litostroj", engineers and technicians of "Uljanik" have shown an impressive technological creativity and industrial aggressiveness in the sphere of research and development and in the production of mini hydro-electric plants. Within a comparatively short time they developed hydro-electric generation units with water turbines suitable for the exploitation of virtually any falls and quantities of water and for continuous or intermittent water supplies (depending on water conditions). Their technology makes it possible to install such units in places where falls of water are availbale such as disused hydro-electrical plants, temporary accumulations, watergates, overflows, remote mountain streams, brooks, waterfalls, etc. "Uljanik's" mini hydro-electric plants, dimensioned for different quantities and falls of water, can either operate individually for a certain consumption area, or can be connected with the existing distribution network. The most important property of "Uljanik's" mini hydro-electric

generation units is the fact that, though fully automatic and designed to operate without human attendance, they are technologically so simple that they can be repaired or even constructed at any local workshop. It is also worth mentioning that "Uljanik's" mini MHG units are delivered for installation in existing engine rooms or in buildings designed and constructed by "Uljanik", or are supplied in specially designed containers for transportation and installation in remote areas accessible only by tractors and helicopters.

In endeavouring to widen the range of its services to fellow developing countries, "Uljanik" is ready to supply its customers with the complete design documentation necessary for the construction or adaptation of facilities, with documentation for connecting the unit with the switchgear, and, finally, with the necessary know-how regarding the dimensioning of the turbine and the complete generation unit, in accordance with the hydrological and technical characteristics of a particular water flow.