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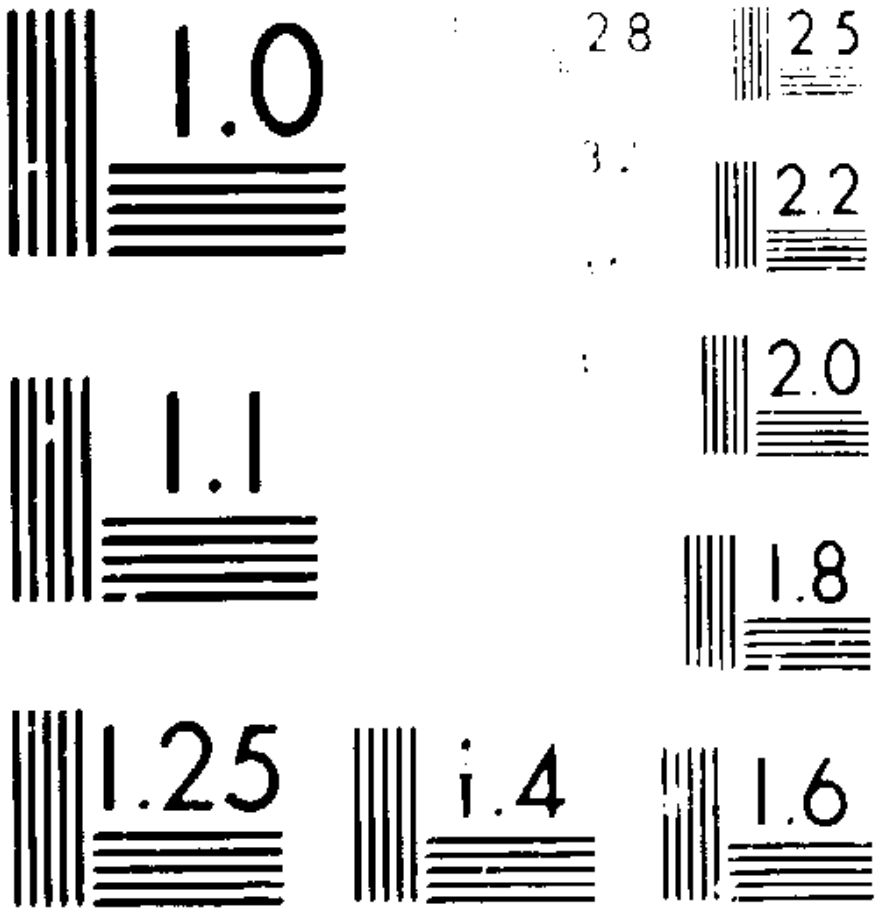
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SMALL HYDRO POWER DEVELOPMENT in the People's Republic of China*

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I. General Situation and Fundamental Experiences of Development of Small Hydro Power (SHP) in China

1. Background

A primary scope has been formed in the development of SHP. China is a country with an ancient civilization. As early as the last stage of western Han Dynasty (206 B.C. - A.D.8), the use of hydraulic trip-hammer for rice husking was recorded in Chinese history. However, the utilization of water power for energy generation took place as late as 19th century. The first hydropower station in the suburbs of Kunming, Yunnaug Province, was built in 1912, with installed capacity of 2300 KW. (Figures 1 and 2).

In old China, there was no power supply in most of the rural areas. According to historical records when New China was born, a small amount of electric power that could be used rurally was limited to the suburbs of several big cities only. The annual rural power consumption was then about 2000 million KWH. The number of SHP stations that had been built is only twenty six with 2800 or more KW.

For thirty years since the birth of the People's Republic, the Government has devoted much attention to the electrification of rural areas and given an impetus to its realization, so that with the great effort made by the masses of peasants, the cause of electrification has been developing rapidly. By the end of 1981, the rural power consumption had amounted to 42,6 billion KWH, occupying 16.5% of the total consumption for industry and agriculture. In varying degrees electricity had been available to 99% counties, 88.9% of communes, 67.2% of brigades and 56.6% of production teams throughout the country.

The classification of rural power consumer is shown in the following table:

Sector of consumption	Electricity consumed (GwH)	Percentage
Irrigation and drainage	15,400	36%
Farm and sideline product processing	9,300	22%
Commune- and Brigade-run industry	8,300	20%
Lighting and domestic use	9,600	22%

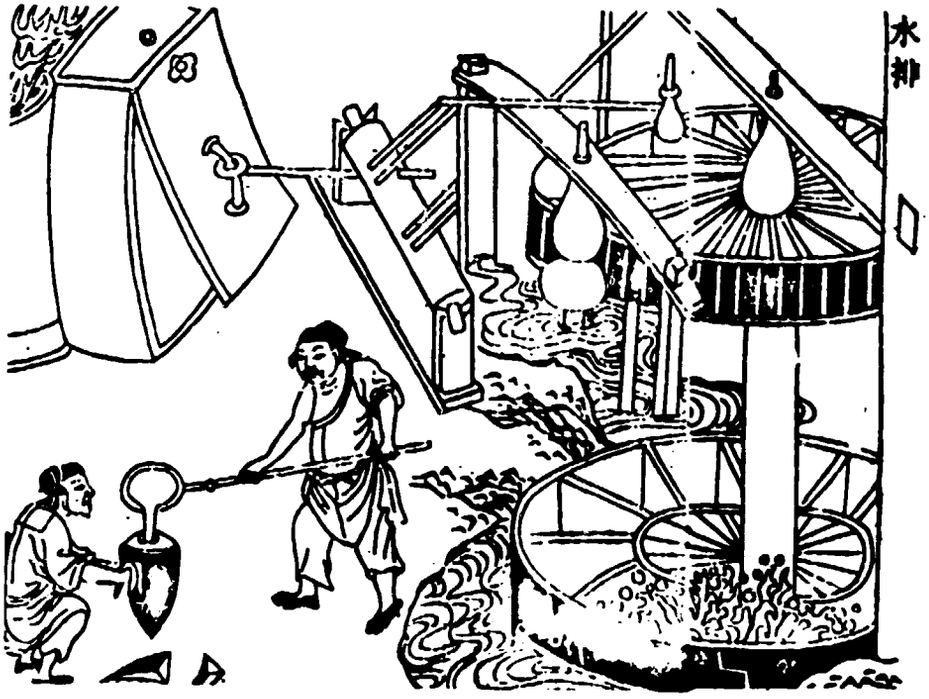


Fig 1

Fig 2

In China, there are two sources of power supplied to rural areas. One is the extension of national grid, the other from the local SHP stations. The SHP of our country has been developing with great speed, and at present its construction has already begun to take shape. Statistics show that by the end of 1982, 86 thousand SHP stations with total installed capacity of 8.01 million Kw had been built in the whole nation with annual energy output 16.3 billion KWH. High voltage lines provided for SHP is amounted to 370 thousand km and transformer rating totalled 30 million KVA. Most of the SHP stations are scattered over ten or more provinces to the south of the Yellow River basin. Among the SHP stations of the whole nation, those in Guangdong, a province in the utmost south of China, comes first in the list, having installed capacity of 1.22 million Kw and annual electricity generation of 2.8 billion KWH totally. Next to those in Guangdong are the SHP stations in Sichuan and Hunan provinces, either of which has set up SHP with installed capacity of more than 800 thousand Kw. Other provinces such as Fujian, Guangxi, Yunnan, Zhejiang, Jiangxi, etc., each have built stations with capacity close to or over 500 Kw.

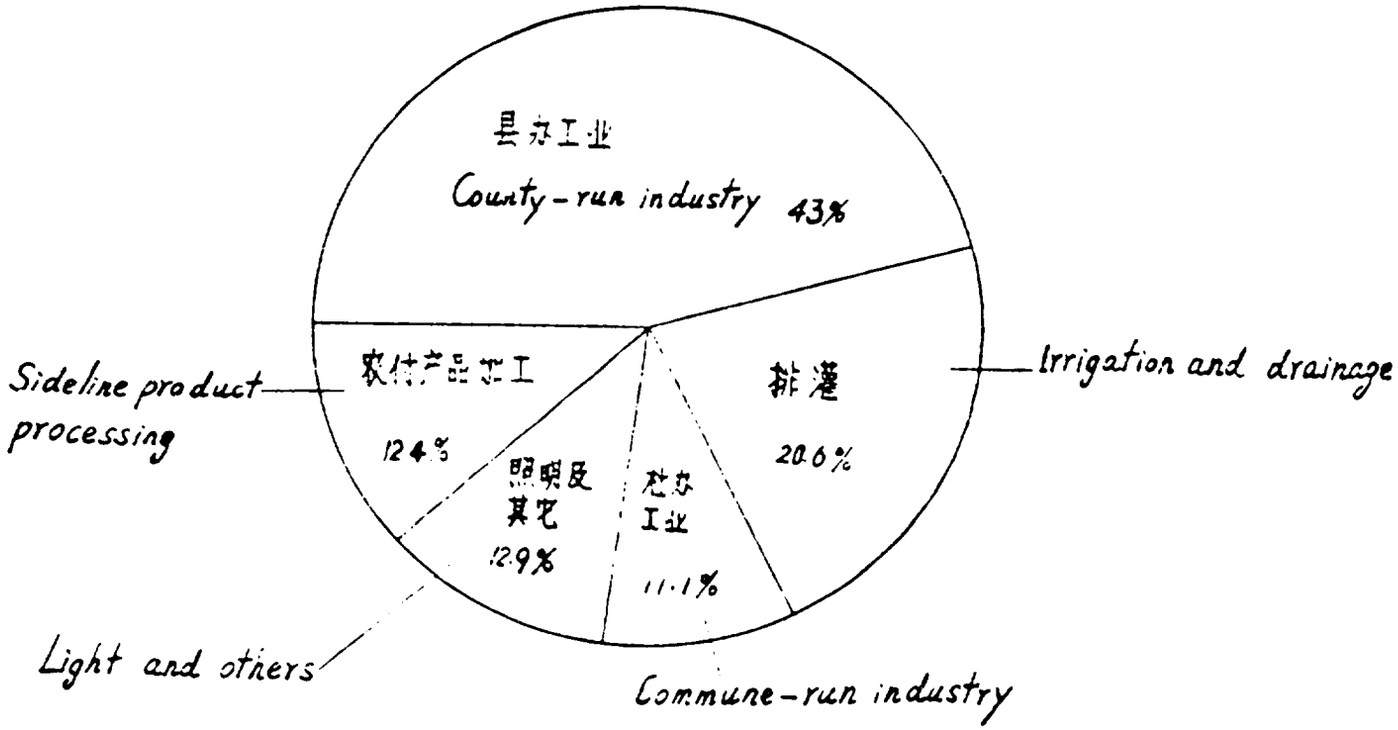
In China, the construction of SHP has been implemented in more than 1300 counties, of which 744 counties get power supply mainly from such SHP stations, and 232 counties have built stations with capacity of 10,000 odd Kw. Some of the counties have ever amounted to 20,000 and more Kw in capacity.

2. The benefits of SHP in China

At present there has been rather a shortage of energy resources all over the world. Under such circumstances, SHP, which plays an important role in solving the problem of rural power consumption, has become a major source of energy in rural areas. Our long years' accumulated experience in developing SHP has proved that it has the features of small size, short duration in construction, lesser investment and giving quickly the benefits into full play. Since the implementation of SHP eliminates environmental pollution as well as economizes on fuels, all the countries in the world have in recent years followed with interest the development of SHP. Officers and experts of the United Nations widely hold that the resources of energy are of great importance for the developing countries.

1981 年全国农村用电构成

The Composition of Electricity Consumption in Rural Area of the whole Nation in 1981



Some foreign friends saw that SHP has been developing everywhere in China, from provinces to communes. How can it be done on such a nation-wide scale? The motivation comes not only from the authorities. This is also a bottom-up action. Meanwhile, the construction of SHP in developing countries needs the support of the Government, and such has been the case in China. The experience of China may be popularized in some of the countries. The SHP in China serves local industries, irrigation and drainage, helps to raise the people's standard of living, etc., and has for many years given its conspicuous benefit into full play in the rural areas. According to its operation experienced in different localities, the functions of SHP may be summed up as follows:

a. It provides cheaper motive power for county-and commune-run industries, promotes their production and increases their output value. For instance, in Yongchun, a county in the south of Fujian Province, 252 SHP stations with a total capacity of 23 thousand Kw has been built, occupying one third of the exploitable capacity. Their annual energy output being 60.00 million KWH, the range of power supply covers two communes and farms, forestry centres, tea plantations and orchards with ten in number as well as 90% of the peasant households. Besides, these stations provide cheaper motive power for several tens of production units, such as coal mining, cement, chemical fertilizer, machinery, textile, paper and porcelain manufacturing, sugar cane pressing, wine and tea making, printing, timber and foodstuff processing, etc. The annual output value of county-run industry has reached 40 million yuan, which has increased by more than four times as compared with the output value of 1969, the year when the first National SHP Conference was held in that county.

b. SHP develops the electric irrigation and drainage project, strengthens the capability of resisting calamities on farmland and increases the production of grain and industrial crops. With SHP, a part of farmland river valleys, terrace fields and land on the slopes can be irrigated, and in high water or rainy seasons the problem of drainage in the local farmland can be solved as well. Some years ago Jing River, the main river in Enping County, Guangdong Province, was brought

under unified control. After cascade development, 130 SHP stations with installed capacity of 360 thousand Kw were set up, and a number of pumping stations for irrigation and drainage developed, which solved the problem of irrigating 280 thousand mu of farmland along Jing River and draining 120 thousand mu of lowlying farmland, thus increasing the production of grain and sugar cane in the whole county.

c. More commune- and brigade-owned industries, farm and sideline product processing are developed. Utilizing electric power for rice husking, flour and fodder grinding, threshing, brick baking, etc. not only saves a good deal of labour, but also lessens the labour strength of the peasants to a great extent. Furthermore, some counties in the mountainous districts of Zhejiang, Fujian, Hunan, etc., have achieved good results in using SHP to dry tea. In 1982, Dashun County in Zhejiang Province dried 7000 odd piculs of tea by electroheat, which occupied one fourth of the total output of the county. With the same method 6360 piculs of tea were dried by Xinzhan County, occupying eight percent of the total output. Drying tea by electricity from SHP can improve its quality, reduce the losses, lower the cost and increase the profit as well as save a large amount of firewood and coal. Another county, Yongchun County, has basically accomplished the mechanization in farm and sideline product processing. The installed capacity for all kinds of machinery for processing amounted to 6000 odd Kw. In 1982 the total amount of grain crop processed was close to 100 million catties.

d. SHP promotes the financial accumulation of the locality so that the personal income of the peasants is increased. The isolated small local grid of Dayi County in Sichuan Province comprises SHP stations with installed capacity of 1300 Kw and small thermal power stations with capacity of 2500 Kw. In 1982, the annual generation of hydropower was 43 million KWH and that of thermal power 2 million KWH. Both kinds of power were supplied to 32 major consumers, such as the prefecture- and county-run coal mine, nitrogenous fertilizer plant, cement plant, sugar, salt and refineries, winery, building material factory, cold storage and tap water companies, etc. In addition, power supply was

available to the towns and the people's communes all over the county. Electric light and wired broadcasting reached fifty percent of the villages and thirty five percent of the peasant households. In 1982, the gross income of SHP in the whole county amounted to more than 300 million yuan, of which 150 million was the net profit. The largest SHP station, Dashui, in the county is possessed of an installed capacity of 5000 Kw, and the investment made in its construction is 300 million yuan. For evelen years since its erection, the part of profit which was turned over to the higher authority has totalled more than 11 million yuan. By adding all the taxes in the accumulation of public finance, has amounted to 12.5 million yuan, which is four times as much as the investment.

e. SHP livens up rural cultural life and creates favourable conditions for the peasants to acquire elementary education and for the development of cultural and recreational activities. Especially, in the villages of mountainous areas which are far apart from big cities and beyond the reach of national grid, SHP is very well received by the masses of peasants.

In recent years, seasonal power consumption for cooking rice, heating up water and baking foodstuffs has been used by the peasants in a few rural areas. The good results achieved are of great significance, especially in the districts where firewood is lacking. To utilize SHP in place of firewood is an effective way of mitigating the contradiction of supply and demand of rural energy, which is of strategic significance in the rural area of China. Danyang situated in the autonomous region of Dong (Tong) nationality in Guangxi Province, is a small county in a mountainous district with 1800 square kilometers of land only. In this county the fuel used constantly for production and daily life was chiefly firewood, irrespective of villages or towns. Since the initial stage when New China came into being, the percentage of forest coverage of that county has decreased from 60% to 30%, the amount of wood kept alive was substantially reduced from 2160 thousand to 1680 thousand cubic metres since 1960, an annual average decrease being 24 thousand cubic metres. Should the case last long, in less than fifty years the resource of wood would certainly be exhausted.

At present, 118 SHP stations with installed capacities of 13 thousand Kw have been set-up by the county. Electricity is in common use by 92% of its production teams, and all the catering and service trades, factories, mess halls and part of the families of staff and workers, taking the utilization of electricity in place of firewood as a principle, popularize the use of ten and more electric appliances such as electric rice cookers, steam pots, water-heating appliances, stoves for foodstuff baking, ovens, etc. In a county-run pastry factory, firewood had been used for baking biscuits and cakes. Each catty of cakes consuming one ketty of firewood on the average, the expenses of fuel consumption for every hundred ketties had been 2.80 yuan. In 1980 a far-infrared electric stove of 30 Kw was installed for baking or toasting, and in 1981 the average power consumption for each catty of cakes was 0.29 KWH. As the consumption of each KWH of electricity means the economization of 4.2 catties of firewood in baking cakes, the baking of every hundred catties of cakes by electric power can reduce 1.07 yuan of fuel expenses. A saving of 38% can be made. Thus, the factory can economize 250 thousand catties of firewood a year; equal to 2600 yuan of fuel expenses. In the porcelain works of that county, firewood had been used constantly. Its consumption had totalled 1200 - 1500 thousand catties a year, so that people of the locality had called the porcelain works "the prodigal of mountain forest". In the heating process, the firewood consumption for each kiln of porcelain had been 700 catties, the cost of which had been 20 yuan, and the yearly consumption 210 thousand catties of firewood.

After using electroheat instead of firewood, each kiln of porcelain consumed 120 KWH of electricity. The price of each KWH of electricity being 8.5 fen, the use of electric power could save 9 yuan a kiln as compared with that of firewood, cutting down the fuel expenses by 48%. So the yearly saving on firewood was 600 thousand catties, which was equal to a saving of more than 6000 yuan.

According to the investigations made by Hunan, Guangxi, Sichuan Provinces, etc., to carry out the policy of utilizing electricity in place of firewood has the following benefits:

a. Utilizing electricity in place of firewood for cooking rice and heating up water is both economical and convenient for the consumers. In a family of five people, cooking rice by electric power accompanied with firewood can make a saving of 51% of the fuel expenses as compared with the use of firewood alone; and 44% of the expenses can be saved if the above cooking is compared with the use of firewood accompanied with coal. Besides, cooking by electric power is quicker and more effective.

b. Using electricity is advantageous to protecting forests and preventing soil erosion, saves the time for part of the peasants to buy firewood and keeps them away from felling trees in the forests. According to the investigation, when firewood was used for preparing three meals a day and heating up water, a family of five people would burn 2000 catties of firewood a year, namely, one cubic metre of timber. What a horrifying amount it is to hear!

c. A part of straw can be saved to give it back to the farmland, which will improve the soil, promote a good circle of ecology and benefit agriculture production.

d. The development of domestic electric appliance industry can be promoted. If the peasants could utilize electric power widespreadedly, there would be a very good market for electric appliances in rural areas.

e. Cooking by electric power can reduce environmental pollution, which is advantageous to the sanitation and hygiene of a family, improve the labour conditions for women, popularize the rural education and raise the cultural level of the peasants.

3. The analysis of SHP resources in China

China is a country with vast territory. Her area is about 9.6 million square kilometres. Two thirds of it is mountainous districts and plateaus, and one third plains. She has a varied topography, but in general, it is high in the western part and gradually lowers down from west to the eastern part. The highest point above the sea level is the Xizang plateau with an elevation of more than 4000 metres, with plains and hills which could be 100 metres below the sea level. The important cultivation areas of China are distributed over the northeast, north China, the Huaike River, the middle and lower reaches

of the Yantze River, the Pearl River delta and inland plains.

China is rich in water power resources. Their deposits occupy first place in the world. The results of general survey show that the deposits of water power are 680 million Kw, of which 380 million Kw are exploitable. The total length of large and small rivers in China is about 40 thousand km, alone the rivers which have a drainage area of more than 100 km^2 each are over five thousand, the natural lakes, both large and small, total two thousand odd, and there are also abundant SHP resources. According to the initial survey, the resources that are suitable for the development of SHP amount to 70 million Kw in capacity, which are mainly scattered in the southwest and the central south areas. Their distribution is shown in the following table:

The Exploitable SHP Resources in China

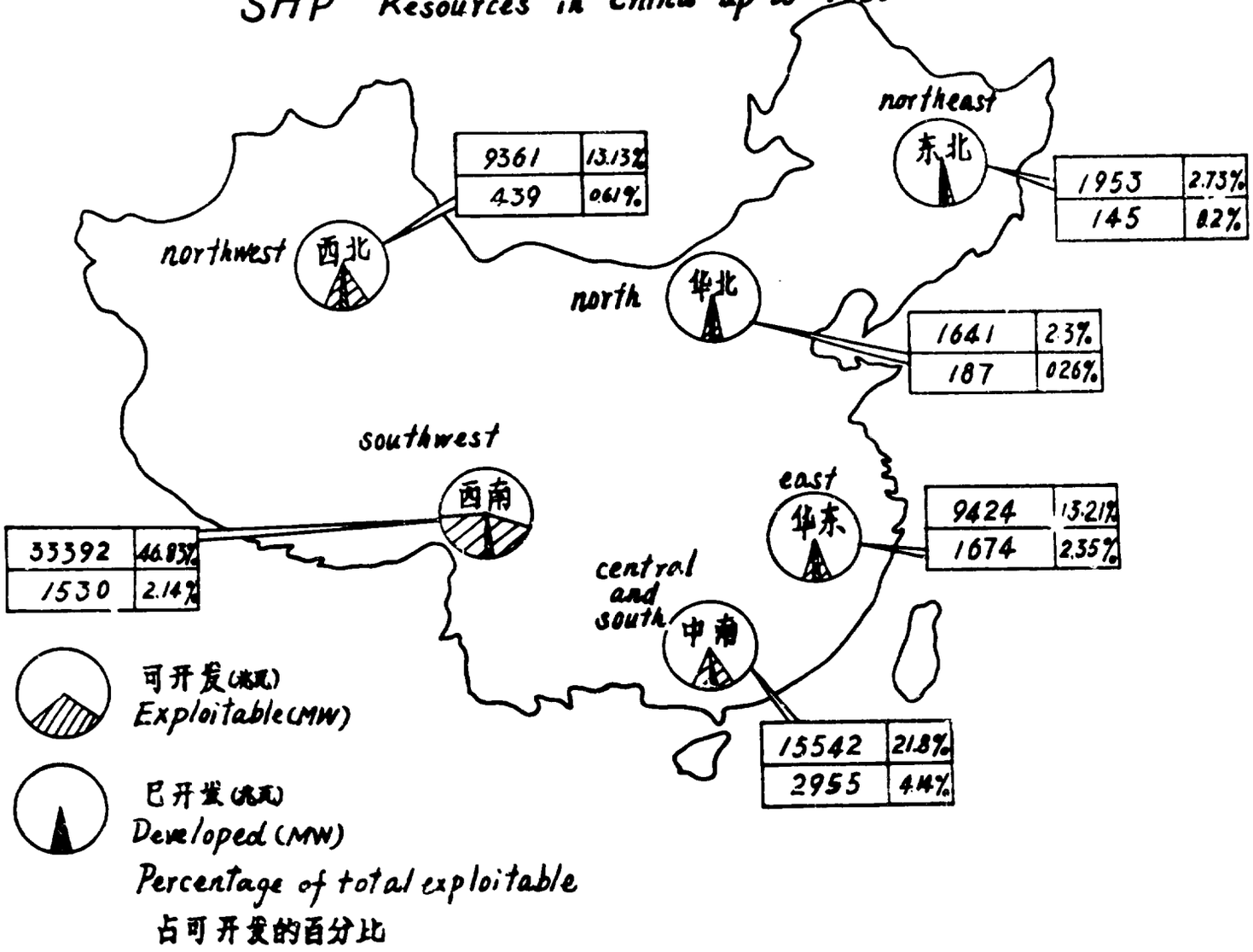
Areas	Exploitable MW	Exploitable %	Developed (MW)
Southwest	33.392	46.8	1,790
Northwest	9.361	13.1	470
Central and South	15.542	21.8	3,390
East	9.424	13.2	1,960
Northeast	1.953	2.7	180
North	1.641	2.3	220
Total	71.313	100	8,010

Among 2000 odd counties in the whole of China, 1100 counties have developed SHP resources with more than 10,000 Kw in capacity, which occupy about half of the total sum of all the counties in China. The amount and percentage of capacity are as follows:

10 - 30 thousand Kw - 43 %
30 - 50 thousand Kw - 22 %
50 - 100 thousand Kw - 23 %
More than 100 thousand Kw - 12 %

中国小水电资源概况(1980年统计)

SHP Resources in China up to 1980



Since the birth of the People's Republic, we have set-up 80 thousand and more reservoirs and 5 thousand odd large and medium irrigation districts. The implementation of SHP combined with the above water conservancy projects can get twice the result with half the effort.

4. The category of SHP and the Classification of Capacity

The category of SHP in China contains SHP stations and small grids whose power supply largely depends upon the former. The unification of power generating, supply and consumption within the range of an area is the concrete sense of SHP in China.

SHP stations are classified by the installed capacity. At present, a station with total installed capacity up to 12000 Kw or single unit capacity up to 6000 Kw is called a SHP station.

The voltage of small grid is classified into three grades in most areas, namely, 35 Kv, 10 Kv and 0.4 Kv. In a few areas there are four grades, i.e., 110 Kv, 35 Kv, 10 Kv and 0.4 Kv.

The above differentiation of capacity of SHP is mainly determined by the consideration of some of the key links that exist in the county level at the present stage. The links considered are the level of power consumption, the capability of implementing SHP, the technology of managing SHP and the production of supplying generating unit equipment. Such classification is on the whole fit for the development of economy and technical competence in the counties, communes and brigades of China today. The implementation and management of SHP can consequently depend on the strength of counties, communes and brigades as well as the masses of peasants. The series of general and specific policies formulated by the Government are therefore advantageous to the development of SHP.

The classification of capacity varies with the development of economy and the rise of power consumption level. Three different classifications have been made since the birth of the Republic. In 1950s there was very little amount of SHP so that the name of rural SHP was classified by the standard

with capacity below 500 Kw. When 1960s came in, SHP possessed a total capacity of several hundred thousand Kw in the whole China, the range of capacity was raised up to 3000 Kw. Since the beginning of the 1970s, SHP has developed rapidly. It has been stipulated that the capacity of SHP is defined as 12000 Kw or less.

Internationally, no unified stipulation has been made about the classification of the capacity of SHP. After the discussion during the First Seminar-Workshop on the Exchange of Experiences and Technology Transfer in Mini Hydro Electric Generation Units, 1979 in Nepal, and the Second Seminar-Workshop/Study Tour in the Development and Application of Technology for Mini Hydro Power Generation, 1980 in the P.R. China and in the Philippines, the classification has been defined as follows:

Small size --- 1000 - 12000 KW
Mini size --- 100 - 1000 KW
Micro size --- below 100 KW

The above three classifications, which is suitable to the present situation of China, has been transmitted to the relevant member countries for reference.

5. Analysis on the three developing stages of SHP

In the early fifties, vast rural districts of China were engaged in the upsurge of co-operative transformation of agriculture. At that time the National Programme for Agricultural Development, which was to direct the agricultural development throughout the whole country, stipulated: "Any water conservancy project capable of generating electric power should carry out simultaneously the construction of medium- and small-sized hydropower stations." Following this policy, a large number of hydropower stations with small capacities had been constructed in various districts through coordinating with farmland water conservancy projects such as small reservoir in hilly area, hydroturbine pump station, dam and hydraulic power station. From the late fifties till 1960, 8983 SHP stations with capacities totalling 238000 Kw had been set up on China. Since this was

just the beginning of the developing period of SHP in our country, the progress was still in slow steps, with an averaged annual capacity-increase of only 20000 - 30000 Kw, and the SHP stations having been constructed by then were all of small capacities, with an average of only 2.6 Kw for each of them. Besides, most of these stations were operated isolatedly and under runoff exploitation without any regulation but with inferior quality in construction, low dependable power and low efficiency of generating unit. In those years, the turbines and penstocks installed in several places were made of wood and bamboo respectively, and the electric power generated by these stations had been utilized solely for illumination and simple processing of by-products in rural areas. Those with a little bigger capacities supplied electric power as kinetic energy utilized seasonally by the small factories in rural towns.

During that period, the main difficulty in developing SHP was the common lack of designs of hydraulic construction and civil engineering for SHP stations as well as lack of technical force for carrying out construction and installation. Therefore department in charge of SHP began to hold technique-training classes on SHP and trained several hundred key members with technical know-how for various provinces. And, at the same time, patterned designs for SHP projects and serial selections of generating-unit types were worked out to solve part of the difficulties.

In the sixties, 1961 - 1970, the capacities of newly increased SHP stations had reached 789,000 Kw, and this meant an averaged increase of 70000 - 9000 Kw in each year. By this time the SHP demonstrated the characteristics of speeding up development and gradually increasing capacities, with an average of 44 Kw for each station. In some districts began the construction of key stations with a little bigger capacities. Some of these were operated by connecting to the national grid, and some others developed their own districts of power supply for local irrigation and drainage as well as for the production of a few factories.

During this period, the SHP in some districts had already began to take shape as a kind of productive force. Hence, in order to promote the development of SHP construction to the national scale so as to bring it in line with the state plan and efficiently solve the problems found in carrying

out constructions, the Ministry of Water Resources and Electric Power, in charge of SHP development, held in 1969 the First Conference of National SHP at Yongchuen county, Fujian, and brought the construction of SHP in line with the official state plan. Thus the state department of materials made special arrangement by assigning various local factories to produce and supply necessary materials such as silicon steel sheet, copper, aluminium, etc., which had been scarce but urgently needed for manufacturing generating units. Such measure gave great impetus to various provinces in their tasks of manufacturing mechanical-electric equipments as well as in speeding up the technical installations of SHP.

From the late seventies to early eighties, SHP in China had developed very quickly, with an averaged annual increase of capacities from 500,000 to 600,000 Kw. In 1979, the capacity increase of that year reached 1060000 Kw. The SHP developed during this period showed the following characteristics:

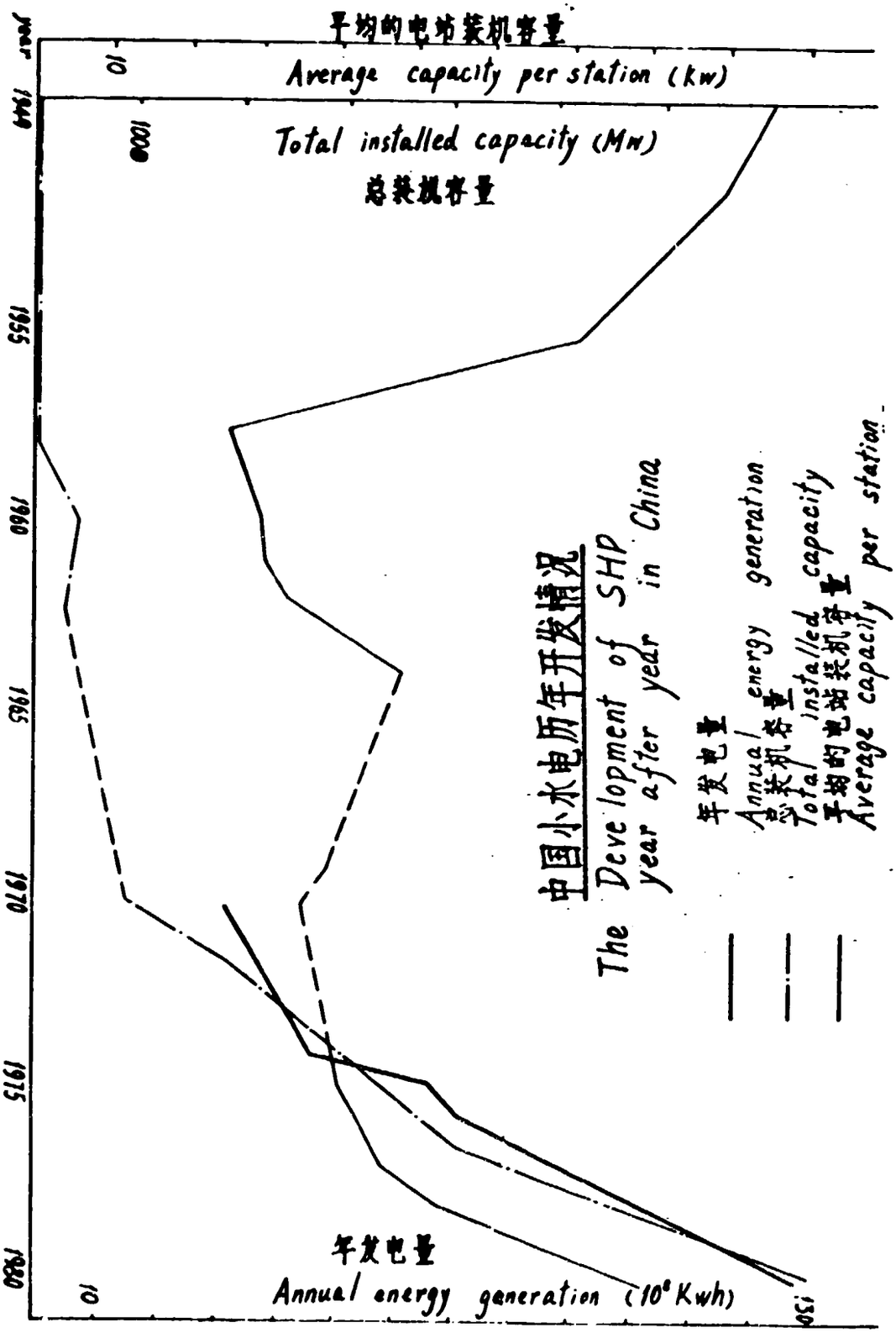
a. Key stations had been increased, the level of reliability promoted, the averaged capacity of single station reached 99 Kw.

b. Distribution districts of SHP had been increased gradually and independent local grid could be set up within the range of a county. Besides, counties with capacities of 10000 Kw generating had also been increased gradually.

c. The quality and capability of power supply had been improved to render more reliable service to industrial and agricultural productions of counties and communes as well as to serve the living needs of people.

d. The surplus electric power began to be utilized to meet the seasonal needs.

e. A series of general and specific policies advantageous to the development of SHP had been regulated and stipulated, and so strengthening the management universally as well as beginning the preparations for realizing the Chinese pattern of rural electrifications in counties selected as experimental spots located in districts with many SHP stations.


平均的电站装机容量
Average capacity per station (kw)
Total installed capacity (MW)
总装机容量
1949
1955
1960
1965
1970
1975
1980
10
1000
10
150
Annual energy generation (10⁸ Kwh)
年发电量
中国小水电历年开发情况
The Development of SHP year after year in China
年发电量
Annual energy generation
总装机容量
Total installed capacity
平均的电站装机容量
Average capacity per station

6. Basic experiences of SHP constructions in China

a. Following the principle of self-reliance, SHP is mainly developed by local people with the support of the state. As to the construction of electric industry, the Chinese Government has been adopting the principle of "walking on two legs". The first was to provide state investment for the constructions of large and medium sized key hydropower stations and stratigically made arrangement for the essential layout of constructions concerning energy resources. The second was to rely on the investment of local authorities as well as on the labour of peasants to initiate the construction of SHP projects and small heat power stations with the support of the state in granting loans and providing techniques, equipments and raw materials. Thus, running by the local people and subsidizing by the state, more SHP can be constructed by local administrations.

b. The inherent characteristic of SHP has been the utilization of dispersed hydraulic resources for supplying electric power to scattered rural areas. In our country, the rural areas are so vast and the residents so scattered that is is impossible to predict when the national grid will be capable of supplying all the power needed by them, to say nothing of the great economical burden caused by such an arrangement. Hence, our Government took the advantage of the above mentioned characteristics and made great efforts to develop local hydro energy resources of small and medium sized rivers as well as to build local SHP stations for the supply and utilization of power in nearby rural areas. Thus, with one station providing power to one area, a local grid can be set up gradually by connecting all these stations. By such an arrangement, our Government not only economized financially and materially together with the saving of large quantity of coloured conductors, but also corresponded with the characteristics of rural areas such as scattered power consumers, seasonal demand of power supply and other various needs for the utilization of electric power. Besides, in some districts, even though continuous supply of power was needed for agricultural utilization, but the requirement was actually not so strict as what had been demanded by industrial consumers in cities.

In recent years, to solve the contradictions caused respectively by flood and dry seasons to the operation of SHP, and to promote the quality and capability of power supply, some districts, through relying on small local coal mines, set up thermal power stations by the mine shaft so as to carry out network operation by connecting SHP with small thermal power stations. As for the local grid near the national grid, it was to be operated by connecting to the latter under the managing principle of "two rail system", realized through the signing of contract. The national grid and local grid are operated in a double circle connection and each of the two grids is responsible to its own consumers.

c. There should be independent local grid for SHP and this arrangement was of crucial importance directly relating the problem of whether the SHP could be developed satisfactorily or not. During the developing course of the SHP, in the district where its electric power was utilized there may be comparatively bigger local industries or important power consumers such as nitrogenous fertilizer factory, etc., and they always demand to raise both quality and capability as well as continuity of power supply. This caused many SHP to connect with each other for the purpose of regulating the surplus electric power with the insufficient and increasing the annual utilization hours of SHP. This has become the consequent trend of the development of SHP.

After the establishment of SHP grid, rational operation can be achieved by effectively dispatching various SHP stations within the grid, and the power distribution can be uniformly arranged by local authority according to the requirements of local industrial and agricultural productions as well as that of the people's living needs. Such arrangement is quite convenient for solving the contradiction existing between power generating and irrigation, contradiction between SHP stations run by county and commune in relating to the start and stop of power generating, and contradiction between SHP stations and local grid in the distribution of profit.

At present, in some counties with numerous SHP, County SHP Corporations have been set up and managed under the principle of --- "Unification of generating, supplying and utilizing". This measure not only

strengthened the management of SHP, but also solidified the result of implementation of SHP by prefectures, counties and communes, thus mobilizing the enthusiasm of local people in the development of SHP.

d. The resource of water conservancy should be fully utilized through overall planning, comprehensive utilization and development by stages. Otherwise, heavy losses to other departments would be caused and, moreover, some SHP will have to change their river courses or to be rebuilt because of ignoring beforehand the needs of irrigation, flood prevention, rafting, fishery and passage for ships during the planning and construction of SHP. In our country, bitter experience as well as rigorous lessons relating to these aspects had been accumulated in the construction of SHP. However, such problems had been attended to in recent years, quite a few districts had carried out their constructions of SHP through overall planning and comprehensive administering and fully utilized resources of water conservancy in flood prevention, irrigation, drainage, rafting, ship passing, fishery, etc. Hence the vast economical benefit from administering drainage areas had been acquired.

e. The national grid gave full support to the development of SHP. For SHP with proper conditions of connecting to the national grid, the latter made every effort to help the former accomplish such co-ordination. For this mutual agreement was signed by both sides and the following principles are to be observed:

i. Integration into the grid voluntarily and withdraw at liberty.

ii. Mode of integration: Single SHP station integrated with the national grid may only generate power without distribution. It may also integrate with the grid individually and preserve its original power distribution region. Or else, some SHP or all the SHP in one county may form a local grid and integrate into the large grid at one or two points.

iii. After the SHP being connected to the national grid, the system of ownership of both the SHP and local grid and the subordinate relationship as well as the financial relationship between them are not to be changed.

iv. In dry season, according to the distribution plan, the national grid is to transmit power to local grid on the basis of meeting the local needs and considering the power supply conditions of the national grid.

v. After the local grid being integrated with the national grid, the power exchange should be mutually or by wholesale provision. The national grid is not supposed to develop direct consumers within the range of local grid except users with large scale consumption. In order to keep the corresponding integrity of the national grid and local grid be advantageous for strengthening the management, appropriate adjustment can be undertaken at mutual agreement.

vi. The national grid seels rated quantity of electricity for the SHP, and set the tariff of electricity from SHP on the principle of neither gain nor loss, and leaving to the local grid all the profit of generation and distribution. When the power of local grid becomes insufficient, the national grid supplies rated quantity of power to districts originally supplied by local grid. The calculation of cost of net electricity supply from either side may be made seasonally or monthly.

vii. For SHP integrating with the grid, unified plan, dispatch, regulation, system and technical standard should all be specified in accordance with mutual agreement. The SHP stations and local grid are to be managed respectively along the line of right of properties.

viii. The SHP should supply power locally and make balance within the local area. Long distance transmission of power is to be avoided.

f. The Government adopts the "policy of protection".
The SHP is directed by the principle of "self-construction, self-management, self-consumption" as well as by the policy of "supporting the SHP with the profit gained from itself", so as to make the implementor of the station profitable. "Self-construction", means that the construction fund of SHP should be raised chiefly by the local founders' own efforts. "Self-management" means that the jurisdiction of SHP, after it has been set up, belongs to the local authority

and the people and will not be taken over by the state. "Self-consumption" means that the power generated is to be utilized by local founders; those who build the SHP will enjoy its benefit.

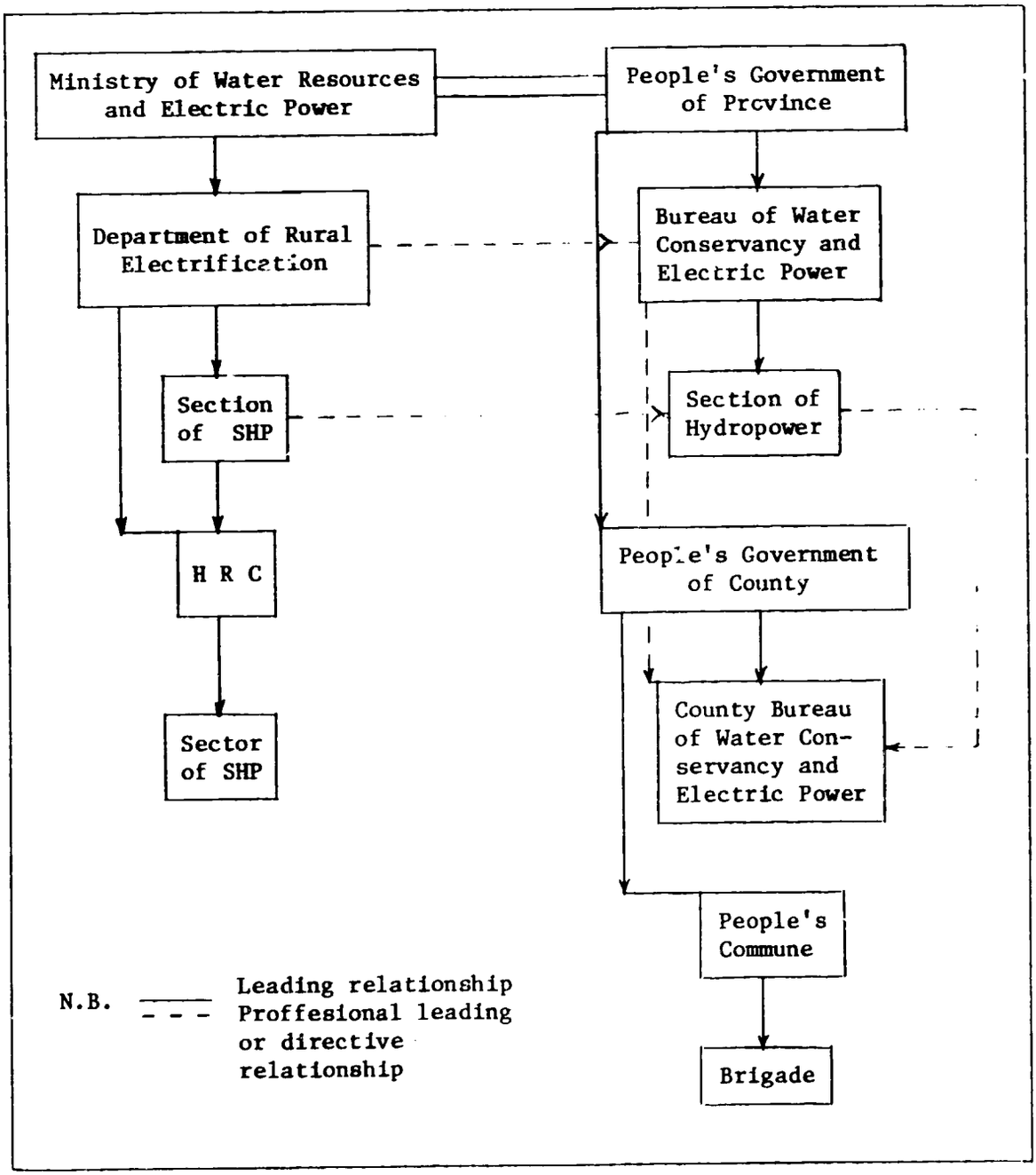
The policy, "Supporting the SHP with the profit gained from itself", stipulated that the profit made from generating and supplying electricity by the SHP together with the profit made from transmitting power by the county network should all be used for the construction and reformation of SHP and not to be brought into the financial budget of different level of Government.

g. To train key technicians for SHP and promote their technical know-how, each year our Government assigns a certain number of college graduates, postgraduates and technical school graduates to various units handling SHP construction and management. Besides, since 1980, every year we held training classes to give technique and management lectures (three months as a term) to personnels of technical knowledge so as to promote them as key members working for the SHP. The result has been proved to be quite satisfactory.

h. Conclusion.

The development of SHP in our country has made rapid progress and certain achievements. However, there are still some shortcomings and difficulties to overcome as well as quite a few inadequate arrangements in various aspects to be improved. Hence we are obliged to learn from other countries. We sincerely wish our foreign friends and experts to kindly help us with your precious advice and suggestions so that we can well improve our work.

i. Block Diagram of Administrative Set-up of SHP



II. Experiences of Independent Operation of Small Hydro Power Grid at County Level (Centralized Dispatching and Independent Operation of SHP in Jinyun County, Zhejiang Province)

1. Independent Operation of SHP Grid

A rather faster development of SHP construction has been achieved in China since 1970's. The annual installation began with $0.3 - 0.4 \times 10^6$ KW at initial stage and reached one million KW at final stage, and total installed capacity also increased from 0.7×10^6 KW odd to 7.5×10^6 KW. At present, out of 2000 or more counties in China, more than 1500 counties have established SHP, among which 720 counties supply electricity mainly from SHP.

China is vast in territory and abundant in SHP resources. Though the operation of SHP varies in form but there are two models at all, i.e., the isolated operation and operating under integration into state grid.

There are generally three types of connection with grid:

a. Integration of SHP station into grid, generating without distribution and its own supplying region;

b. After connecting with the state grid, SHP keeps its own supply-region and connects with state grid at only one or two points; and

c. Several SHP stations constitute a county, or a regional grid and are also connected with the grid at one or two points only.

The above mentioned third type may be called a small hydro power grid, which can further be divided into two forms.

One form of small hydro power grid, owing to lack of reservoirs with strong regulating capability in it could not co-ordinate within water regulation, electricity generation, supply and consumption. Electric power and energy cannot be balanced. It is connected with the grid at more than two points, and has to rely on the state grid in electricity supplying and reception. When it is disconnected with the grid it is difficult to operate by itself.

In another form of small hydro power grid, there are reservoirs with strong regulating capability, so water regulation, electricity generation, supply and consumption comply with one another, thus keeping electric power and energy practically in equilibrium. By means of one or two points of connection with the state grid, it can be either connected or disconnected with the state grid. After disconnection, frequency and voltage regulation, water regulation, electricity generation, supply and consumption can be solved by itself and thereupon keep the SHP grid in reliable operation. In this form of SHP grid, only electric and technical connections are related to the state grid. It is independent in operation and administration. For the time being, let us call SHP grid with such operating capability the "independent operation".

The Jinyun county grid in Zhejiang Province is one of the independent operating SHP grid. Table I shows that "Self-Generation, Self-Supply and the surplus electrical power being transmitted to the state grid" has been achieved in this SHP grid. The SHP grid, which does not depend on the state grid but contributes to it, is well acceptable to the state grid.

2. Main Experiences of Independent Operation of SHP Grid of Jinyun County, Zhejiang Province.

In order to realize independent operation of a SHP grid, due considerations should be paid for planning, design and constant improvement of fundamental construction, but its all the more important to strengthen management of operation, adjustment water regulation, electricity generation, supply and consumption in this SHP grid to maintain relative equilibrium time after time. The realization of independent operation of Jinyun County grid is due to centralized dispatching in water regulation, power generation, supply and consumption at early stage. Early in 1977, SHP of the county was only 3000 odd Kw. However, soon after the Dayang reservoir, a larger reservoir with high capability of regulation had been constructed just to store water for generation, the County Administration, in accordance with the features of SHP grid of the whole county, gave a unified management for the reservoirs concerned with generation, grid as well as consumers.

Table I : Information of operation of the whole county in some typical months

Time \ Item		Rain fall (mm)	Energy generation (10^4 KWH)			Energy generation (10^4 KWH)	Amount of electricity exchanged with State grid (10 KWH)		
			cascade stations	other SHP	Total		Output	Input	Net output
1978	Jan.	47.2	62.34	38.36	100.84	109.36		8.52	-8.52
	Apr.	111.0	30.68	86.87	115.55	99.55	16.00		16.00
	June	78.89	78.89	87.84	166.73	104.73	40.52		40.52
	Aug.	80.7	176.46	31.11	207.57	115.00	99.57		99.57
	Nov.	26.9	148.32	8.98	117.37	117.37	1.09	1.02	0.07
	Whole year	1243.3	1149.34	518.84	1668.18	1291.67	393.15	16.64	376.51
1981	Jan.	40.8	182.56	17.73	200.29	230.38	10.58	49.67	-30.00
	Apr.	185.7	139.61	172.35	317.96	229.66	88.69	0.39	88.30
	Jun.	118.4	187.79	67.03	254.82	240.05	23.59	8.82	14.77
	Aug.	239.1	143.44	99.50	242.94	259.56	15.37	31.99	-16.62
	Nov.	78.5	136.18	73.27	209.45	197.41	35.21	23.17	8.04
	Whole year	1538.2	1933.34	848.04	2781.38	2578.65	411.75	209.04	202.71
1982	Jan.	5.7	256.31	41.67	207.98	266.20	37.17	5.39	31.78
	Apr.	143.7	264.03	114.12	398.15	289.81	90.13	1.79	88.34
	Jun.	205.6	186.66	70.72	257.38	248.00	21.95	12.57	9.38
	Aug.	226.9	199.63	77.81	277.44	167.85	110.85	1.26	109.59
	Nov.	129.2	258.24	79.48	337.72	250.21	88.69	1.12	87.57
	Whole year	1418.4	2785.12	919.98	3705.10	2874.45	878.61	47.95	830.66

Notes:

1. November is dry month, April and June are rich water months, August is rich in water in case typhoon exists, or otherwise, it will be dry month.
2. During rainy season, cascade stations generate less electricity while other SHP stations generate more. In case of water shortage, cascade stations generate more electricty through the capability of reservoir-regulation while other SHP stations generate less or stop generating.
3. In rainy season, water is stored in reservoirs and surplus electricity is transmitted to state grid. In dry season, discharging water of reservoirs can maintain electricity supply according to the plan.

A dispatching station for electric power of the SHP grid was established to balance the hydro energy, electric energy, electric power and energy of the developed SHPs in the county from the view point most favourable to the national economic benefit of the county, thus realized the unified management of water regulation, generation, supply and consumption. Consequently, not only economic benefit owing to centralized dispatching was obtained but also balanced development of reservoirs, stations, grid and electric loading of the whole county were promoted. Some contradictions in the course of operation were practically solved such as:

a. Power supply to the state grid during rich water season is limited, while during dry season, supply from the state grid is inadequate to meet the demands;

b. During rich water season SHP stations in the county compete with each other for the generation of electricity;

c. During rich water season power supply of SHP stations in the county exceeds the demand, while in dry season, deficiency of generation causes shortage of electricity for the consumers;

d. Generation of electricity does not comply with irrigation, etc.

The experiences of SHP grid of Jinyun county show that centralized dispatching for water, electricity generation, supply and consumption can be proceeded without greatly increased installed capacity of SHP in the county, construction of large regulating performance, or readiness of relevant conditions. So long as the fundamental construction of SHP has a sound basis, centralized dispatching should proceed in due time. During the course of dispatching operation, improper considerations of the original planning and design will expose gradually and then improve from time to time fundamental construction project, which has to be repeated during the successive operations.

Main Experiences of Realization of Independent Operation through Centralized Dispatching in Jinyun County:

a. Development of SHP and increase of electric loading rise alternately and maintain relative equilibrium.

b. The establishment of the county's SHP company is a measure taken by the government of the county to solve the key problem of realizing the centralized dispatching. The company takes the overall management of utilization of reservoirs of stations connected with the small grid, generation units and operation of the grid. Possessing the commanding authority for reservoir-control and operation of electric equipment for generation and transformation belonging to the SHP company, the company could unify the relation among water, electricity generation, supply and consumption from the point of view of economic income for the whole county.

c. The dispatching stations of Jinyun county possess great commanding authority. Although many reservoirs owned by communes serve irrigation mainly, the right of discharging water also belongs to the dispatching stations, thus irrigation and generation were unified. After five years' practising, reservoirs, stations and grid have all shared more or less the economic benefit brought forth by the centralized dispatching. A "command" and "subordinate" relation was made between the dispatching station and its subordinate reservoirs, stations, consumers of water and electric loading thus promoting complete equilibrium for the development of industry and agriculture of the whole county.

d. The planning and layout of the county grid was comparatively logical and its linking of lines is simple and distinct, easy to form a SHP grid. The linkage among SHP stations, between stations and electric loading, SHP grid of the county and state grid is simple and distinct. The two grids were connected at one point only, where the amount of energy exchange was recorded, thus providing the basic technological conditions for the realization of centralized dispatching and independent operation of SHP.

e. Independent set-up of administration. The administration of personnel, finance and dispatching all belongs to the SHP company of the county except business management relation and electric connection within the subordinate area of the state grid.

f. Independent price of electricity. In accordance with the requirements for developing production of the county, price of electricity was fined and regulations of expense-payments for the fee decided by the local authority in order to enlarge reproduction.

g. Implementation of policy "Supporting the SHP with the profit gained from itself". The profit gained has been spent to develop SHP or make the grid a complete set.

3. Brief description of development of SHP grid in Jinyun County

Before 1957, Jinyun County practically had no electric power. Only in Huyun town, the capital of the county, there was a 24 Kw charcoal generator for electric illumination.

Up to 1959, it extended to three units of oil generators with a total installed capacity of 88 Kw.

In 1960, the first low water head SHP station of 2 x 64 Kw was built.

Later on, some SHP and small thermal power stations were built. By the end of 1968 the total installed capacity of small thermal power had amounted to 185 Kw and that of SHP amounted to 308 Kw. A 14-kilometer long transmission line of 10 KV connected all SHP with small thermal power throughout the county to form a small grid.

In order to accelerate the development of industry and agriculture, Jinyun county put the weight of electric construction on SHP from 1971 onwards, and at the same time also developed small thermal power. By the end of 1972, small thermal power had developed to 707 Kw and SHP to 1328 Kw. Within four years SHP had increased four times or more and two electric loading centres had formed respectively at Hu town and Huyun town.

From 1972 to 1980, SHP dominated both electric power construction and generation in Jinyun county. During this period, although the installed capacity of small thermal power had some increase, the energy generation decreased year by year to reverse position. By the end of 1976, the amount of SHP generation had reached 99.8% of the total amount of the whole county. After 1981, small thermal stations were eliminated and a complete SHP grid of generation and supply was formed in the county.

Information regarding installed capacity of SHP and small thermal power, energy generation, table and curves of county-total output value of industry and agriculture are shown in table II and graphs 1 and 2.

4. Features of SHP grid in Jinyun county

Graph 3 is featuring the SHP grid in Jinyun county:

a. relative concentration and vicinity between stations and loading furnish favourable conditions to place central substations in the county;

b. through the central substation, a 35 KV connection line is used to keep contact between Huyun town and Hu town, between county grid and state's grid, Southern or Western system of Zhejiang;

c. from each central substation, some main lines are laid out along stations or loading distribution points. Each line is connected with some SHP stations or consumers;

d. in the districts where loadings are relatively concentrated and conditions are allowed to build SHP stations, such as Ling-Tov-Fang and Nan-Ken districts, one or more SHP stations were set-up to realize local equilibrium of electricity generation, supply and consumption in a small SHP grid and to get low power exchange in the grid and loss in transmission line. This kind of small SHP grid can also be of independent operation and disconnected with the state grid in case of necessity. This adds to the flexibility of SHP grid.

5. How to realize centralized dispatching

Centralized dispatching needs unified administration of water, electricity generation, supply and consumption. The dispatching programme is based on loading curve.

a. Determination of daily loading curve of operation. Loading curve is mainly derived from accumulation and analysis of historical statistics.

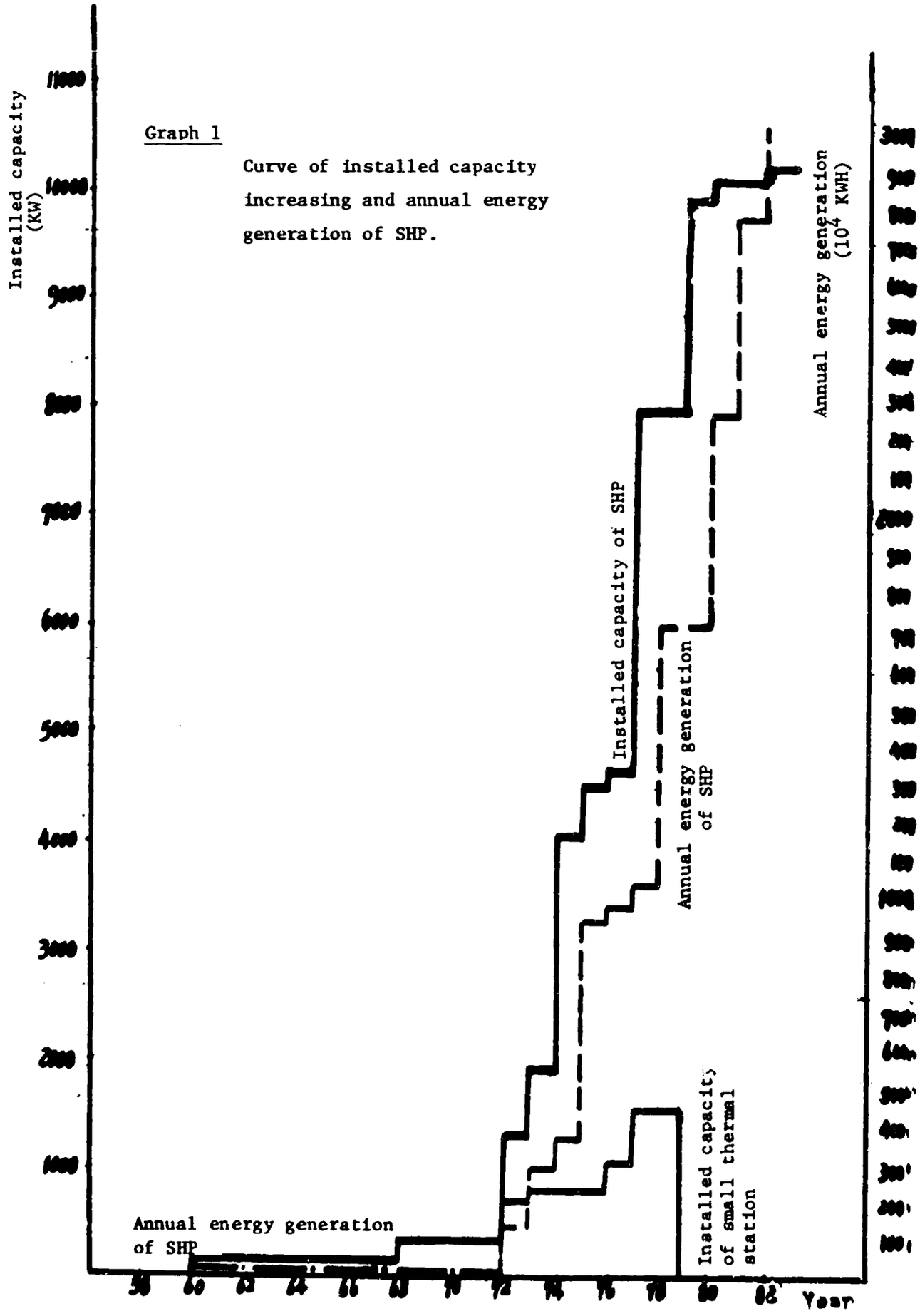
Table II : Diagram of main figures of electric power construction - Jinyun County

Year	Installed capacity (KW)		Max. Loading (KW)	Annual energy generation		County-total output value (10^4 yuan)	
	Small thermal station (KW)	SHP (KW)		S.th.P	SHP	Industry	Agriculture
1958	37.3	-	40	-	-	224	2020
1960	88	128	100	27.4	12.3	920	1801
1968	185	308	250	25.9	3.6	336	2071
1972	707	1328	1200	20.1	148.8	1440	4665
1973	791	1968	1300	9.44	287.9	1707	4765
1974	791	4050	1300	17.65	330.4	1426	4962
1975	791	4575	1700	2.45	902	1233	4708
1976	1061	4645	1800	0.47	947.5	1467	4169
1977	1561	7940	2500	0.2	1083.5	2222	4383
1978	1561	7940	3500	2.9	1668.2	2694	5008
1979	1561	9865	4500	-	1662.6	3192	5575
1980	1561	10350	5500	3.7	2235.2	4150	5713
1981	-	10350	6000	-	2781.4	4199	7872
1982	-	11150	6500	-	3705.1		

Note: Total profit of the county: 3 million yuan or more
profit from SHP: 1 - 2 million yuan or more

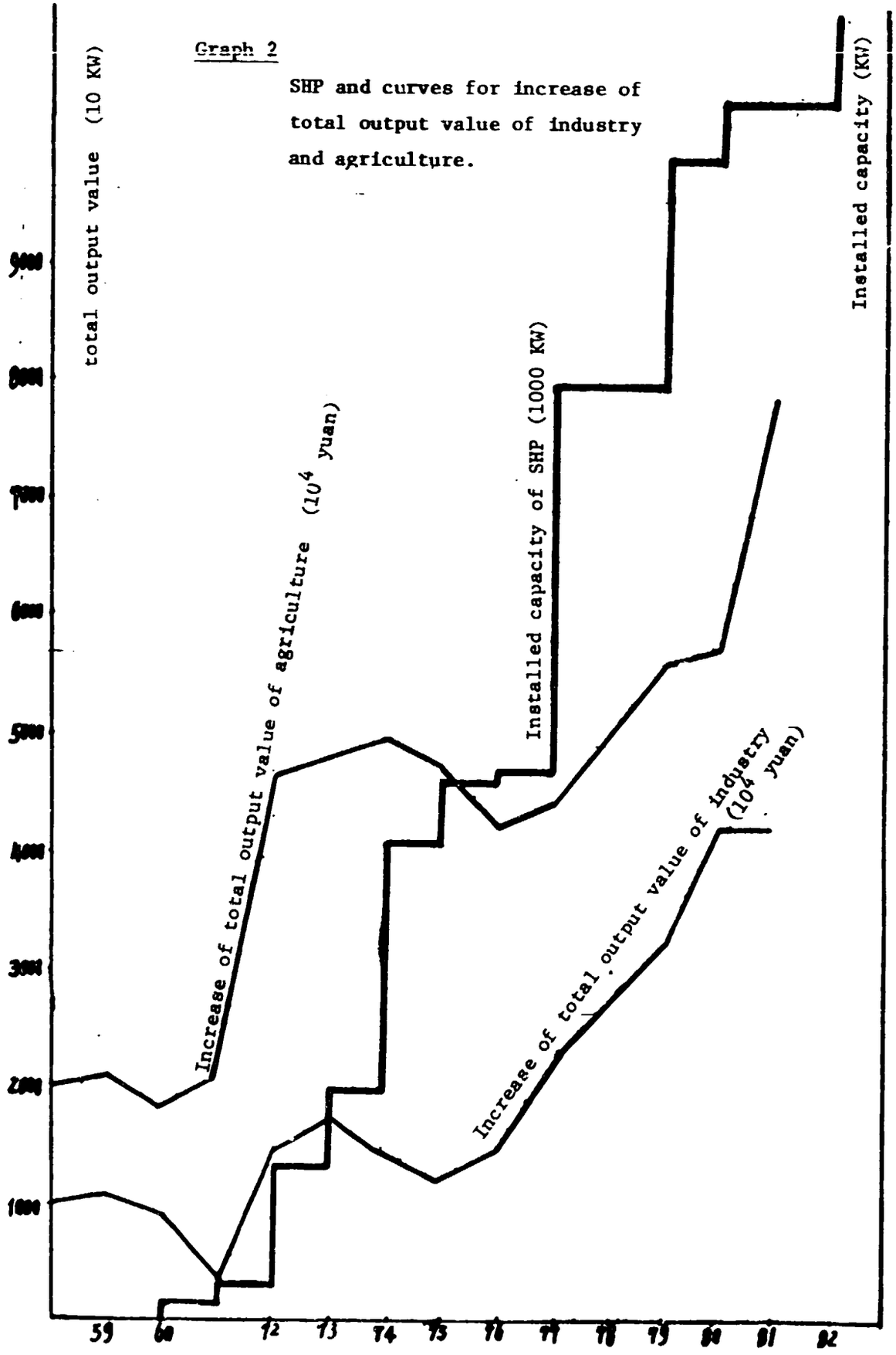
Graph 1

Curve of installed capacity increasing and annual energy generation of SHP.

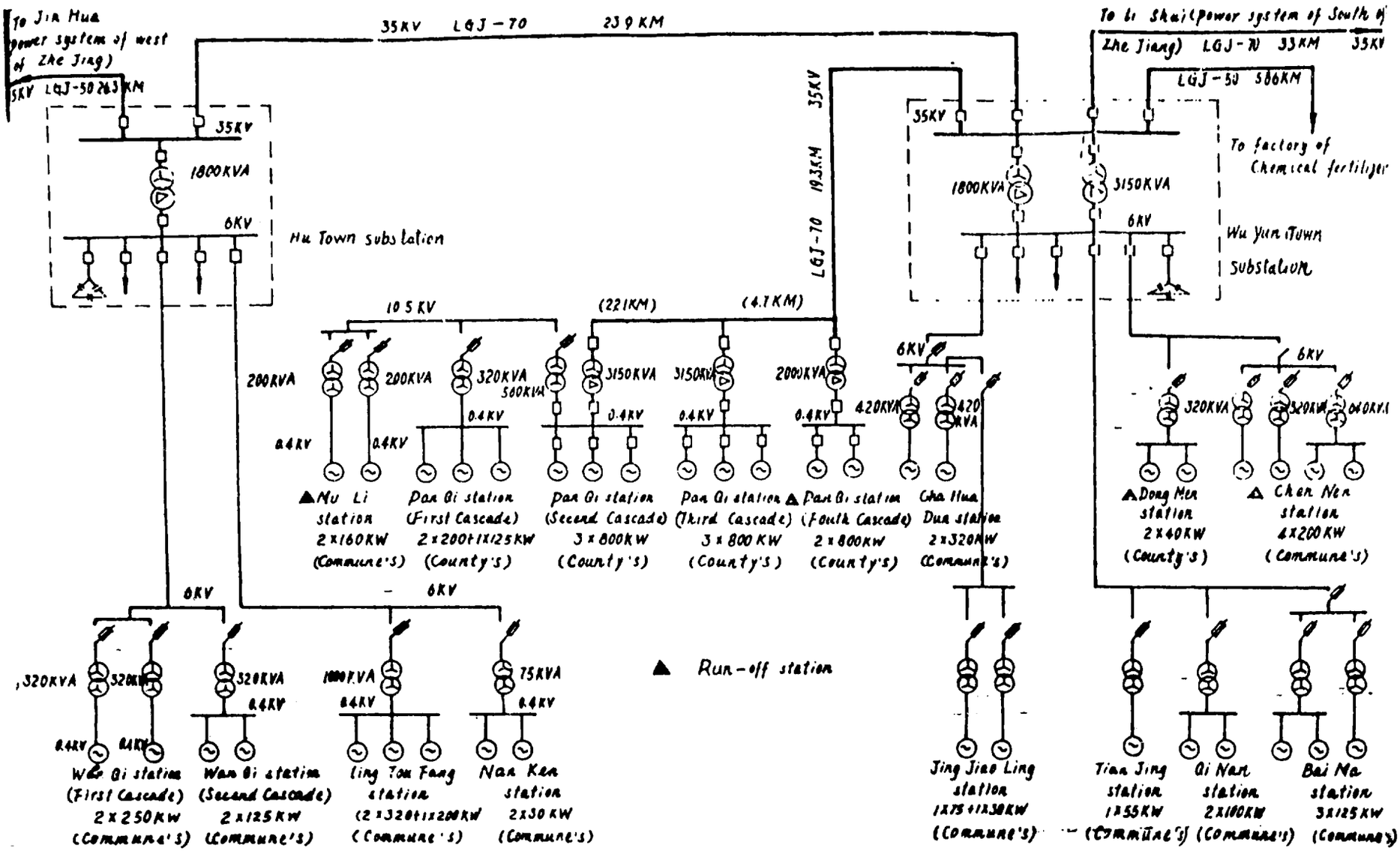


Graph 2

SHP and curves for increase of total output value of industry and agriculture.



Graph 3: Grid diagram of Jinyun County



Operating daily loading curve is decided by practical operating loading curve of the present week or recent days, besides this, close contacts with the consumpers are important.

Daily loading curve is divided into two kinds; operating daily load curve for paralleling to and releasing from the state grid.

Typical daily loading curves of SHP grid in Jinyun county are shown in the attached Graphs 4, 5 and 6.

Graph 4: Daily load curve of operation for releasing from the state grid on 6 May 1982.

Graphs 5 and 6: Daily loading curve for paralleling with state grid on 22 May 1982.

b. Determination of operation mode of a station according to loading curve.

The operation mode of a station should be determined according to loading curve and regulation characteristics of the stations, and can be described with working position of each station on the loading curve, as shown in Graph 7.

Take the operation mode of a SHP station in Jinyun county as an example: (refer to Graphs 3 and 7)

i. Run-off stations (such as: Muli, Dongmen, Chen-Nen and Fourth cascade of Panqi) carry base load, generate as much electricity as water is available. Sometimes, reservoir stations with rather low regulation characteristics also carry base load, such as Nanren, Jing Ling Jiao, Tian Jing, Qi Nan, Wan-Qi 1 and 2 cascade stations, Ling Tou Fang and Bai-Ma SHP stations.

ii. Reservoir stations with certain regulation characteristic also carry medium load such as Cha-Hua-Dun, Ling-Ton-Fang, sometimes Wan-Qi 1 and 2 cascade stations, Qi-Nan and Bai-Ma stations. These stations generate electricity in daytime when loading is heavy and stop at night when loading is light. How many medium load and the duration time, namely, the position occupied on the loading curve, are determined by amount of discharged water from the regulation reservoirs as shown in Graph 7.

iii. Reservoir stations with stronger regulation characteristics (such as Pan-Qi cascade stations) carry peak load.

These stations regulate frequency when released from the grid.

When medium load is carried in separate parts by reservoirs with certain capability of regulation (as described in point ii. - page 34) distinct peak loads on the daily loading curve becomes comparatively smooth. Peak loads being reduced to small peak loads with medium gradient as shown in Graph 8. When SHP grid is integrated with state grid these peak loads can be easily compensated. When SHP grid is released from the state grid, it is also not difficult to regulate frequency by reservoir stations with stronger capability of regulation.

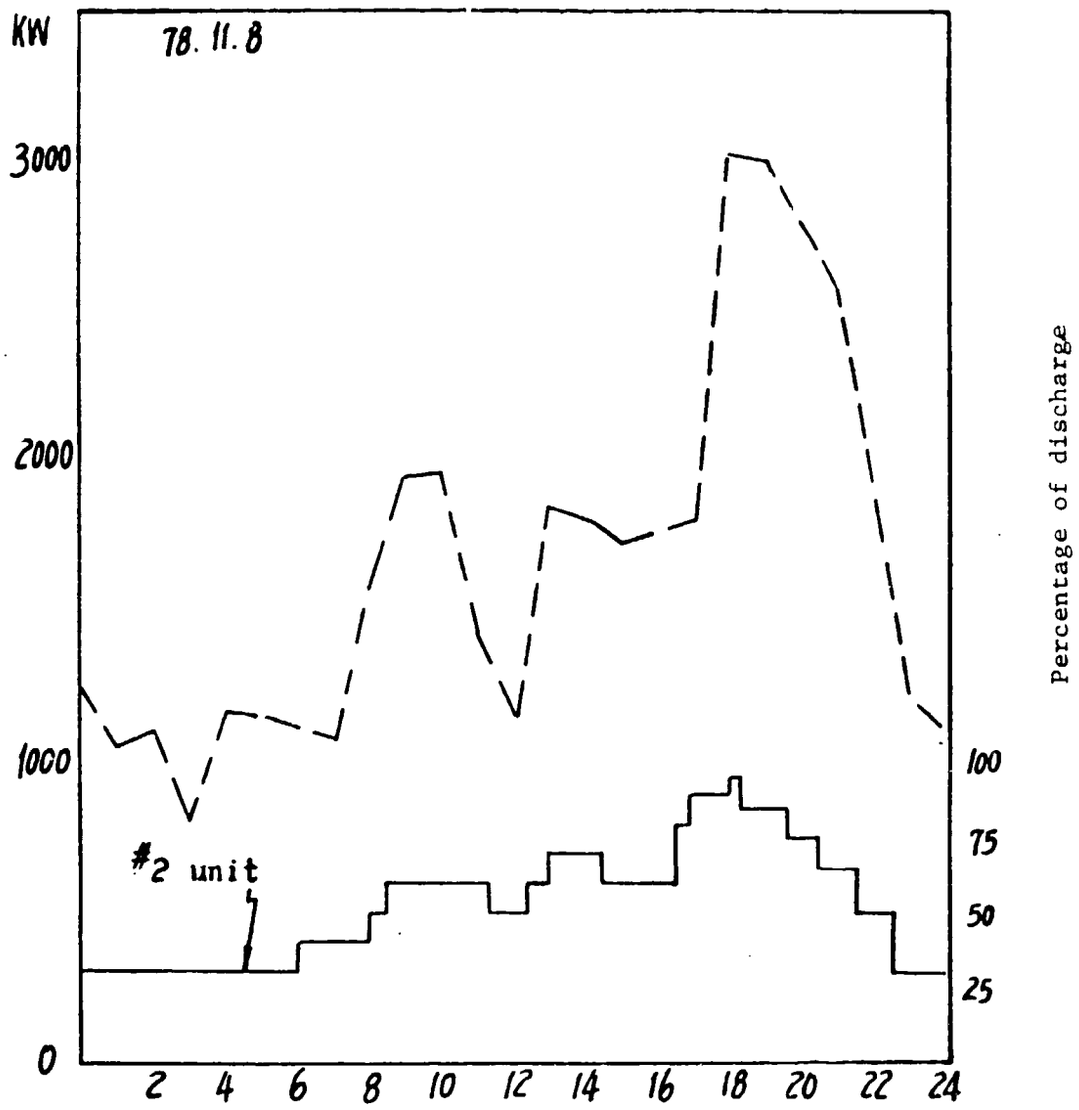
c. Determination of principle discharged water from large reservoirs according to loading curve.

As described in paragraph b, Pan-Qi first cascade station of Dayang reservoir with stronger capability of regulation carries peak load. The key to bear the peak load is to determine the principle of water discharge of the reservoir according to the loading curve (Graph 5).

In the loading curve of Jinyun county grid on 13 May 1982, it is shown that peak loads and low loads appeared four times on that day, as well as some moderate variations of load. Considering that distance from Pan-Qi first cascade station to the following cascade stations are not equal, thus time of water flowing accordingly varies from several tens of minutes to several hours, and that generator units of reservoir stations are not similar in their characteristics, the operation of gate valves has the following features:

i. Gate valve no.1 is the main regulation valve.
ii. Gate valves no.2 and no.3 units are auxiliary regulation valves. Alternation of opening no.2 or no.3 gate valve depends on running conditions of generator units as well as experiences.
iii. In view of the time of water flowing in a channel, gate valves should be opened in advance or closed in accordance with load variations.

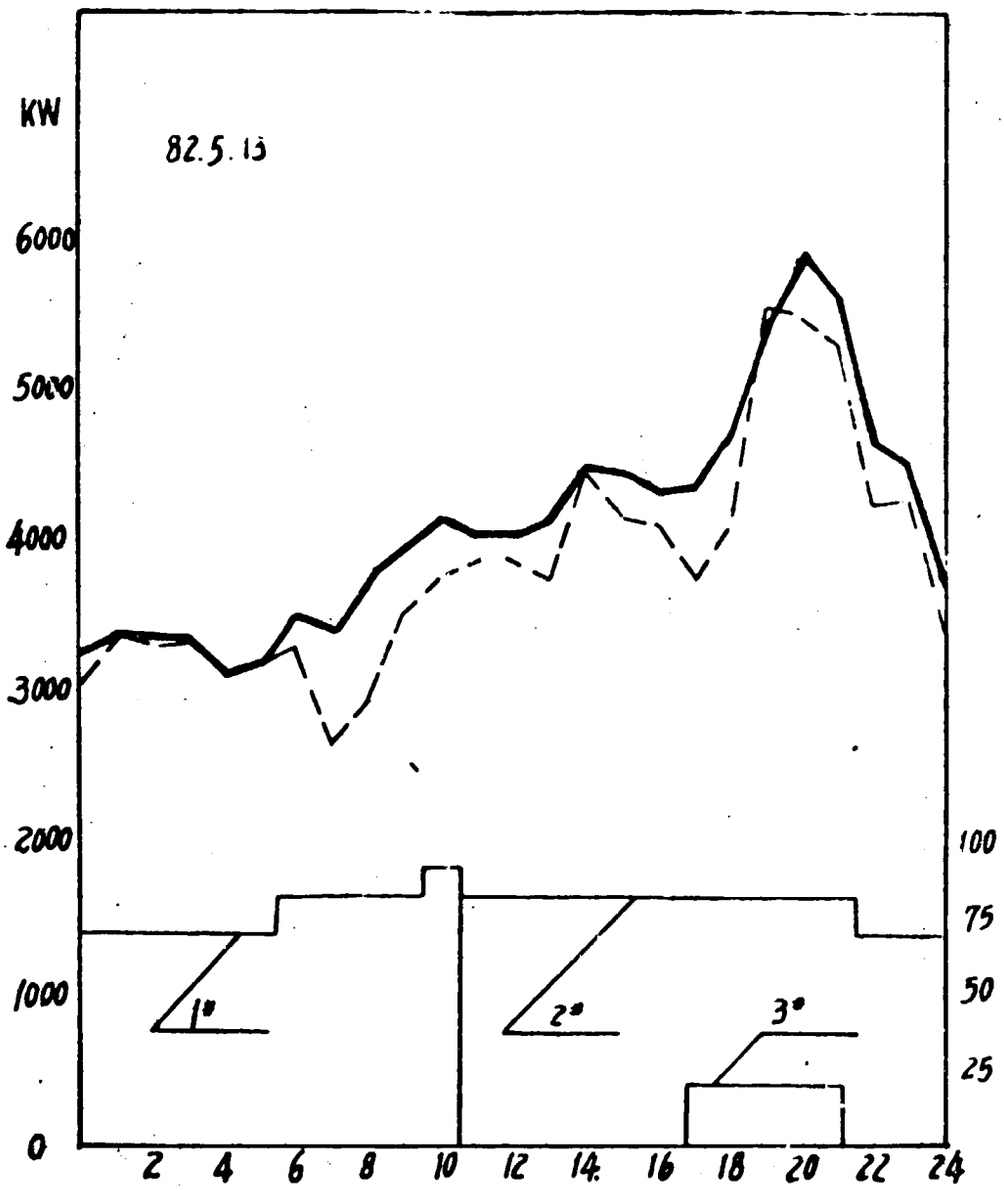
Graph 4: Operating daily load curve for releasing from state grid



- - - - county load

——— curve of discharge of unit for Pai Qi station (first cascade)

Graph 5: Operating daily load curve for parelleling with state grid.
Maintenance balancing operation for county grid and state grid, in abundant period)

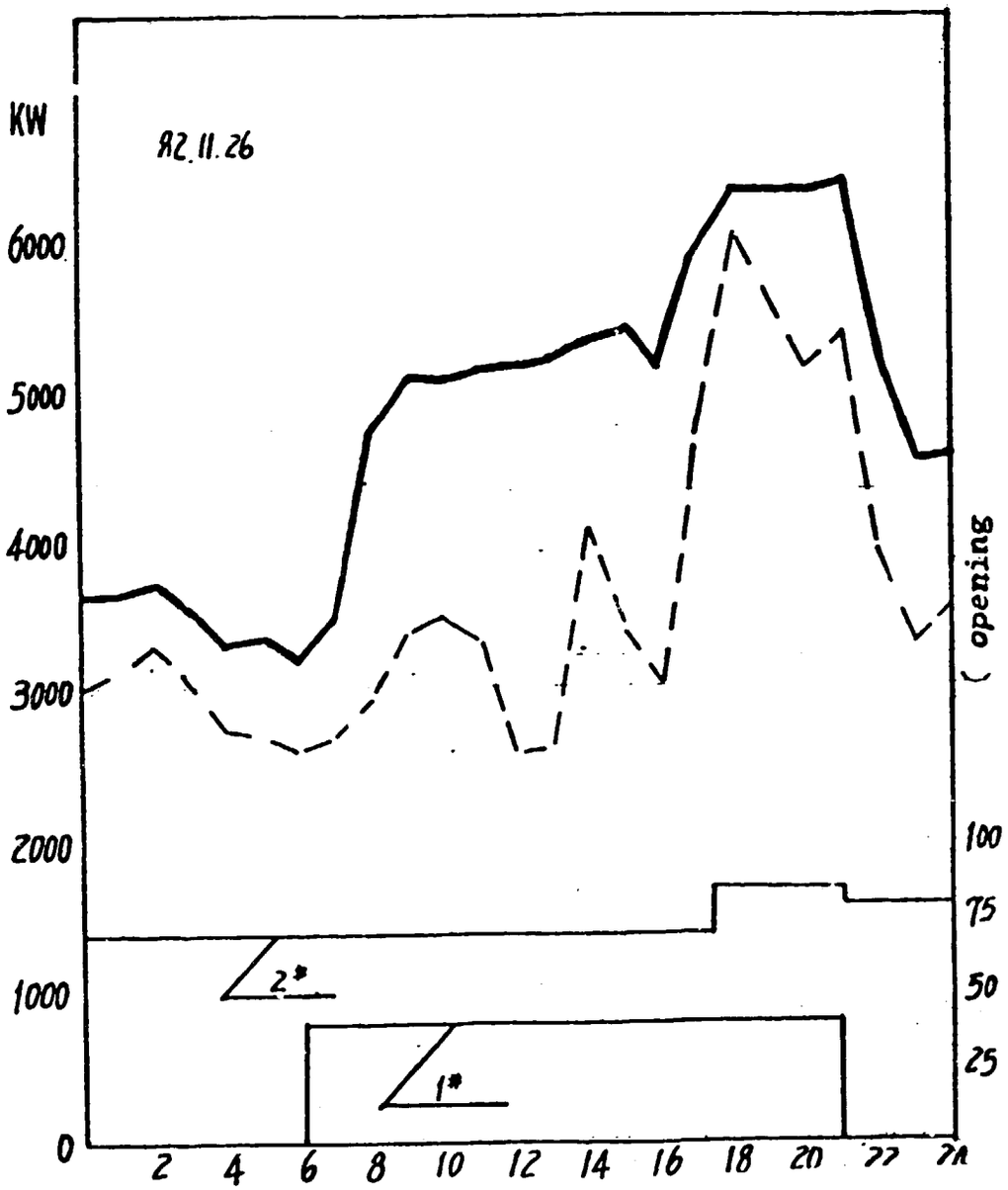


curve of generating power

curve of county load

curve of discharge opening of unit for Pai Qi station (first cascade)

Graph 6: Operating daily load curve for paralleling state grid
(Transmitted to state grid)

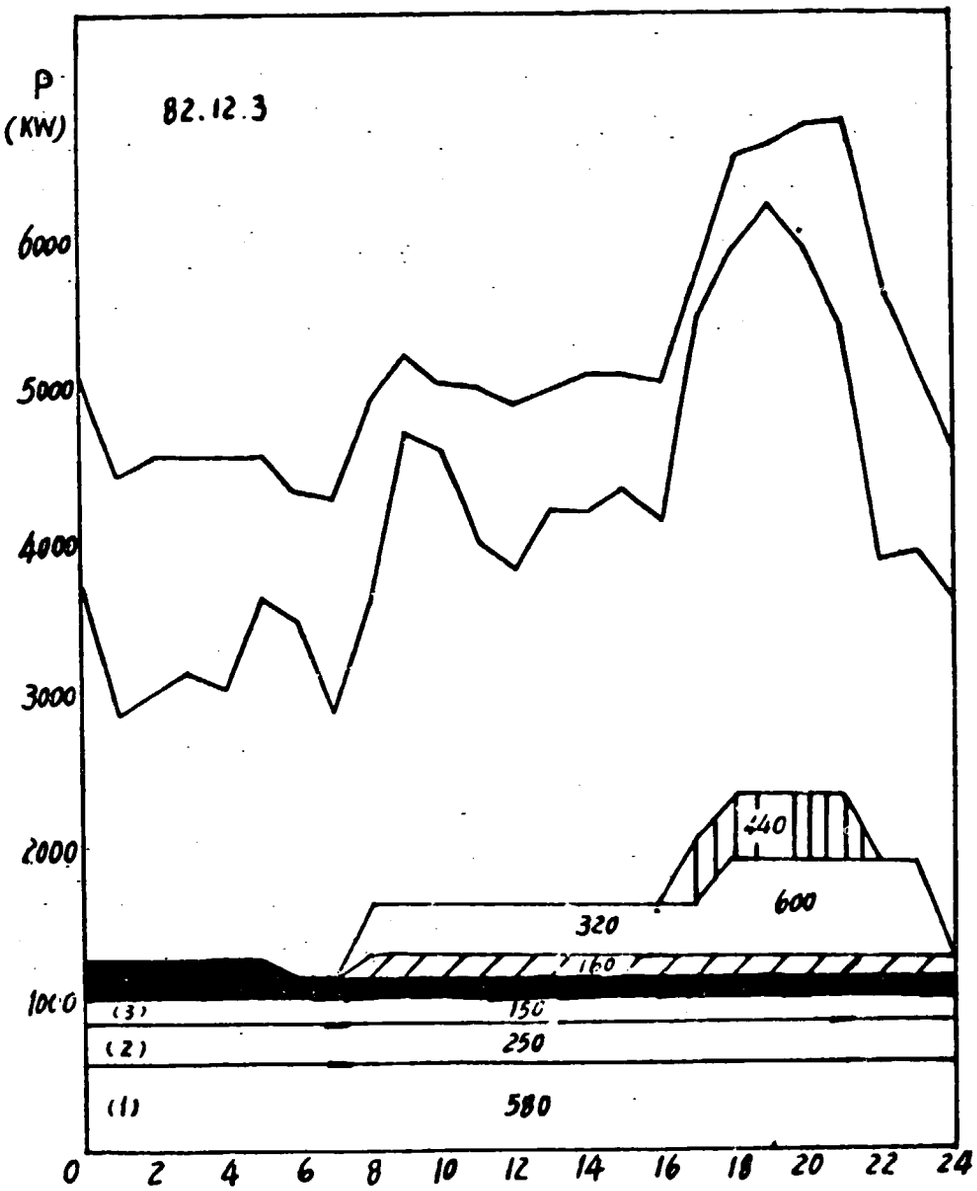


curve of generating power

county load

Discharge opening of unit for Pai Qi station (first cascade)

Graph 7: Curve of distributing power for paralleling operating station



(1) Chen Nen Station

(2) Wan Qi Station (First Cascade)

(3) Qi Nan Station

Mu Li Station

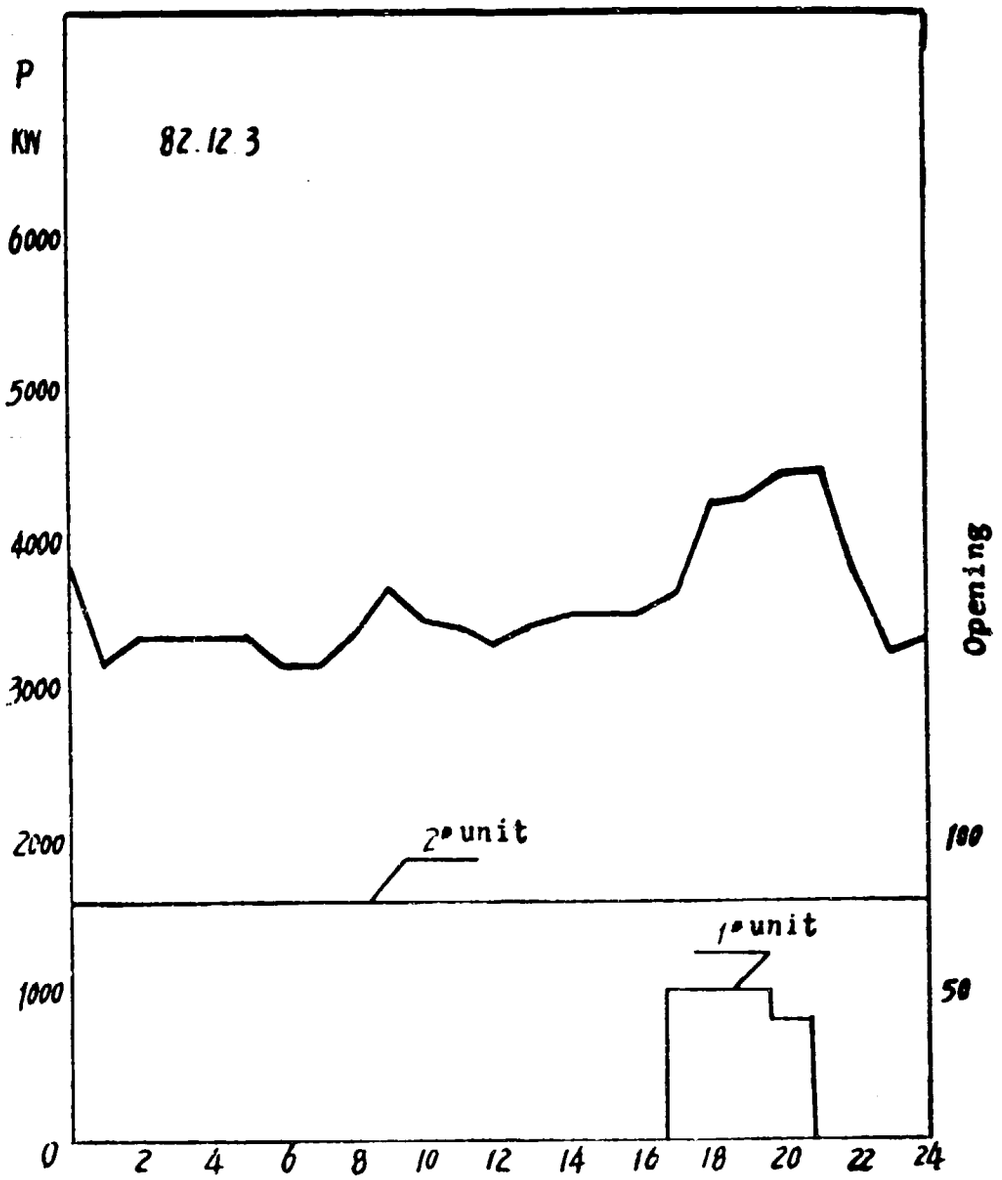
Bai Ma Station

Cha Hua Dun Station

Ling Tou Fang Station

Pan Qi Cascade Station

Graph 8: Curve of generation power of Pai Qi cascade station



Curve of generation power of Pai Qi station

Curve of discharge opening unit for Pai Qi station (first cascade)

6. Economic benefits of cascade stations obtainable from centralized dispatching

After realization of centralized dispatching of SHP grid, it is very important to identify the best operation mode, especially the optimal operation of a cascade station.

The optimal operation of a cascade station mainly includes:

a. Generator units under best running conditions; and
b. Best co-operation mode between stations, etc.

It is rather complicated to study numerous problems concerning optimal operation. Therefore we are unable to develop and summarize it here and now. However it is obvious, from the instance of the Pan-Qi cascade station, that economic benefits can be obtained from centralized dispatching.

Pan-Qi cascade station is located in Pan-Qi river basin. The river is a tributary of Hao-Qi River in the Oujiang river system. It is 30.2 kilometers long, with drainage area of 84 square kilometers. In this region of high mountains and steep streams with swift current, a 600 odd meter water head can be utilized. It is a project of high water head at low rate of flow in a small river basin. On the upper part is Dayang reservoir with storage capacity of 11.9 million cubic meters, which serves perennial regulation.

Pan-Qi cascade station is the backbone of Jinyun county SHP grid. With Dayang reservoir capable of efficient regulation, it bears regulation of peak loads when integrated with the grid and serves regulation of frequency when released from state grid.

The operation mode of Pan-Qi cascade station results in variable loading of the generator, hence require variable amount of water.

The long distance open canal of Pan-Qi cascade station takes long time for water to pass through it as shown in Table 3.

Table 3: Lengths of open canal and time for water to pass

Name of Station	Pan-Qi 1-2 cascade	Pan-Qi 2-3 cascade	Pan-Qi 3-4 cascade
Distance of canal between stations	2045 meters	2492 meters	9000 meters
Time for water to pass	± 50 minutes	± 60 minutes	± 180 minutes

Owing for the long time taken for the water to pass and slow variation of water level, the co-operation among cascade stations can hardly meet the demands of peak loading regulation and frequency regulation. If only a single station's output is regulated to meet the variation of loading, the water flow to and from the station would either be insufficient, stopped or overflow.

Through centralized dispatching, variation of load can be reasonably allocated to each of the cascade stations and even to each generator unit in accordance with tendency of load variation and time for the water to pass through the canal. When load is increased or decreased, all stations increase or decrease output simultaneously according to operation features of units and amount of water flowing from the canal as well as time taken for water to pass and other factors. Information regarding method of calculation of co-ordination among cascade stations is available in articles "Method of frequency regulation" and "Method of micro-regulation of forebay", summarized by the Bureau of Water Conservancy and Electric Power, Jinyun County.

Table 4 shows the resulting data of decrease of water consumption and increase of annual energy generation and operation hours obtained from the centralized dispatching of Pan-Qi cascade stations.

Table 4: Information of Operation of Pan-Qi Cascade Stations

Year	Installed capacity (KW)	Annual rain fall (mm)	Annual energy generation power (10^4 KWH)	Increase of water stored in reservoir (10^4 M^3)	Water consumption rate of generation (M^3/KWH)	Annual utilized hours	Notes
1976	2925	1556.2	745.03	-	2.9069	2547.1	operation stations 1st, 2nd cascades
1977	2925	1665.2	748.69	+191	2.9244	2559.6	
1978	2925	1243.3	729.72	- 29	2.1629	2494.8	Excluding the installed capacity and annual generation of 3rd cascade in generation for 6 months
1979	5325	1178.8	1241.82	-124	1.2451	2332.1	operation stations 1st, 2nd, 3rd cascades
1980	5325	1468.5	1475.17	+239	1.1900	2770.3	- " -
1981	6925	1538.2	1984.69	+377	0.8834	2866.0	- " -
1982	6925	1409.3	2785.12	-119	0.8373	4022	channel construction of Payang reservoir put into operation

Table 5: Main Figures of Connected SHP Grid, Jinyun County

No.	Name of SHP Station	Installed capacity (KW)	No. of units	Name of reservoir	Regulation capability of reservoirs	Capacity of reservoirs (10^4 m^3)	Collection area of rainfall (KM^2)	Water head (M)	Conduit length (M)
1	Pan-Qi 1st	2x200+1x125	3	Dayang	Perennial	1190	19.7+6.2	36	180 m tunnel
2	Pan-Qi 2nd	3x800	3	Dayang	Perennial	1190	19.7+6.2	220	2045
3	Pan-Qi 3rd	3x800	3	Dayang	Perennial	1190	19.7+6.2	205	2492
4	Pan-Qi 4th	2x800	2	Dayang	Perennial	1190	19.7+6.2	92	5540
5	Chahuatun	2x320		Chahuatun	Weekly	105	76	29	100
6	Wanxi	2x250		Hongkenghing	Weekly	30	9	220	2850
7	Lintoufang	2x320+1x200	3	Lintoufang	Perennial	298	4.5	196	1050
8	Muli	2x160	2	-	-	-	14	160	450
9	Shennan	4x200	4	-	-	-	1048	9	2400
10	Baima	3x125	3	Baima	Monthly	285	43	25	-
11	Xinan	2x100	2	Xinan	Weekly	163	39	20.5	-
12	Jinlingjia	1x175+1x30	2	Jinlingjie	Monthly	107	7	25	-
13	Dongmen	2x40	2	-	-	-	850	2.5	1500
14	Nankeng	2x30	2	Nankeng	Monthly	35	3.9	15	-
15	Wanxi	2x125	2	Wanxi	Monthly	363	26	24	-
16	Jianjin	1x55	1	Jianjin	Monthly	40	2	86	200

7. Benefits of Reservoirs Increased through Centralized Dispatching and Regulation

Because of the poor regulation characteristics of a small reservoir, there is little economic potential in the operation of a single station. But this changes a lot if several reservoirs collaborate with one another in the operation through centralized dispatching. In Jinyun county, there are altogether 16 stations which are connected with the SHP grid. Except for 3 run-off stations, the other 13 stations have regulation reservoirs of definite capacity as shown in detail in Table 5.

In some commune's stations, reservoirs are all of weekly regulation with similar characteristics, but the time required to collect rainfall runoff into reservoirs varies, owing to differences in water head, storage capacity, and area of rainfall collection. With centralized dispatching, this time difference can be adopted to stagger the generation for different stations, in order to generate more electricity with less loss of water.

Take Cha-Hua-Tun and Wan-Qi 1st cascade station for instance. They are all of weekly regulating reservoir. Table 5 shows that Cha-Hun-Tun station has low water head (29 m), large capacity of reservoir (105×10^4 m^3), while Wan-Qi 1st cascade station has high water head (220 m), small capacity of reservoir (30×10^4 m^3) and small area of collecting rainfall (9 square kilometers). During process of dispatching, Cha-Hua-Tun station with large area of rainfall collection and large capacity of reservoir is arranged to discharge water through generation in advance according to the feature of low head before rainfall. After the rainfall, Cha-Hua-Tun station continues generating. After three days when water in reservoir is going to be empty, Wen-Qi cascade station,with a small area of collecting rainfall and small capacity of reservoir, is put into generation in due course.

Through this regulation, Wen-Qi 1st cascade station may have some loss of water and economic income, but it is beneficial to the whole grid. The contradiction of competition in generating power among SHP stations is settled in rich water season. So, as long as the dispatching is reasonable all small reservoirs participating in co-operation in a grid will gain economic benefits.

Economic benefits gained by the Cha-Hua-Tun and Wen-Qi 1st cascade station in co-operation under centralized dispatching are shown in Table 6.

Table 6: Economic Benefits of Co-operation under Centralized Dispatching

Name of SHP station	Installed capacity (KW)	Regulation capacity or reservoirs (10^4 M^3)	Year of operation	Annual rainfall (mm)	Annual energy generation (10^4 KWH)	Annual utilized hours	Analysis of economic benefits
Chahuatun SHP station (commune's)	640	105	1977	1665.2	166.27	2598	Annual rainfal of 1981 slightly less than that of 1977. Increased annual energy generation 57.45x10 KWH Increased percentage 34.6%
			1978	1243.3	192.21	3003	
			1979	1178.8	170.18	2659	
			1980	1468.5	224.1	3502	
			1981	1538.2	223.72	3496	
Wanqi 1st cascade station (county's)	500	30	1977	1150.8	150.22	3084	Rainfall of 1981 slightly exceeding that of 1977. Increased annual energy generation 29.77x10 KWH Increased percentage 19.3%
			1978	880.1	130.63	2613	
			1979	895.8	112.24	2245	
			1980	1307.1	155.09	3102	
			1981	1298.8	183.99	3680	

8. Problems and Ways of Improvement

Much experiences have been gained from operation of Jinyun county grid through centralized dispatching, but some problems still exist:

a. Storage capacities of existing reservoirs in the grid are rather small only amounting to ten million or more cubic meters and the installed capacity of single unit is only 800 Kw. When releasing from the state grid, due to insufficiency of regulation characteristics of the reservoirs, independent operation of this SHP grid is insufficient and still has to rely on the state grid to some extent. Hereafter, the county will build some larger reservoirs and set some units with bigger capacity in order to strengthen the capability of frequency and voltage regulation, ensuring reliability of independent operation of the grid when released from the state grid.

b. In the county grid there are some commune's and brigade's small SHP grid which have contradictions with the county grid and it is necessary to strengthen their capability of independent operation.

c. Degree of automation and telemechanization of backbone stations of the county grid are rather low, thus require improvement.

d. Layout of part of 10 KV grid is not so reasonable and has to be improved.

e. System of organization is not so perfect and level of dispatching and management have to be raised.

f. Conditions of equipment is not so good, defects have to be eliminated.

9. Conclusions

In order to give full play to the superiority of SHP and fully utilize cheap electrical power during abundant water seasons, the Party Central Committee of China demands that before 1990, the rural areas of some counties should realize electrification for daily life appliances, such as cooking, heating, water boiling and temperature lowering, thus saving fuel-woods and protecting forestry and vegetable cover. To solve contradictions between SHP and state grid, to promote the development of SHP, it is required to make reasonable planning as well as to strengthen and improve the capability of independent operation of SHP grid, beginning with the planning of river development and power supply.

We believe that policies set by the Party Central Committee for development of SHP will lead us to a new way of development. In regions where conditions are favourable, independent operation of SHP grid will promote the development of SHP.

III. How to Establish Indigenous Manufacturing Capability of Small Hydro Turbine Equipments

There are rich water resources in China. According to the statistics in 1980, the potential of SHP is about 150 million Kw of which 70,000 thousand Kw can be developed. 10 thousand Kw capacity is nearly distributed over half the counties in our county, which is the important material base of developing SHP. Before liberation, there were only 26 SHP stations with a capacity of 2000 Kw, all units of the stations were imported from abroad. During 30 years after the foundation of the new China, about 100 SHP manufacturers have been built with annual productive capability of one million Kw. In China the installed capacity of SHP units is up-to-date near to 7 million Kw which amounts for about one third of total hydro power equipment and can supply one third of electricity for the agriculture of the country thereby promoting the process of the agricultural electrification.

With the development of production the identification of SHP capacity has been expanded continuously. It is stipulated in the Trial Series Chart in 1965 that the axial flow turbine with capacity less than 1000 Kw and diameter below 120 cm, and mixed flow below 84 cm are of small type. It is stated in the Formal Type Chart in 1973 that the mixed flow below 84 cm and the axial flow below 120 cm are of medium-small type. There was no capacity limit provided. In fact, the capacity of the axial flow is less than 1000 Kw, and the mixed flow less than 6000 Kw. In the Meeting of Technical Experience Exchange of SHP convened in Nepal in 1979, the Chinese representative proposed that the hydro power plants with a total installed capacity up to 12 MW, each unit below 6 MW are classified as small hydro power generation (SHP) (according to the prospect of SHP potential in the country). This is a demarcation line of small hydro turbine capacity at present in our country.

Seriation of Hydro Turbine Products

China has a vast landscape, varied topography with plateau climbing to the roof of the world, chain of undulating hills, boundless stretch of plain, long coastline and numerous islands. Since the hydraulic condition varies from place to place and the water flows and head dealt with an extensive range, the different kinds of units have been developed such as mixed, axial, impulse, tubular and inclined jet impulse, etc., and the various structure forms are also springing up. Take tubular for instance, there are siphon, vertical shaft, bulb and shaft extention, mixed-blade and adjustable-blade, direct and indirect drive (planetary gear or helical gear), etc.

In accordance with the characteristic parameters of the turbine, the turbine runner seriation is graded rationally and the runner model is also named by specific speed.

Runner dia seriation

The classification for two neighboured diameters must consider the fact that when two products are operated within the output range from 50% to 100%, the average rate of efficiency dropping must be within the allowable range. If varieties are too many, it has no advantage for production, but if the classification of diameter is too little, the large dropping of average efficiency is uneconomic in consequence. So, least but rational number of varieties are required to meet the needs of the user. The diameters of the mixed flow seriation are ranged as 25, 30, 35, 42, 50, 60, 71, 80, 100 and 120 cm and its dropping of average efficiency takes 7 - 8 % with tolerance diameter of 1.19. For axial flow form, through the use of the adjustable blades to solve the problem of sharper characteristic curve of propeller blade. The tolerance diameter can be also taken larger, and its diameters of seriation are 40, 60, 80, 100 and 120 cm. Owing to its smooth efficiency curve of the impulse type, the diameters of seriation are 45, 55, 75, 90 and 110 cm, etc.

In China, the Official Seriation Chart of Turbine was issued in 1973, and the Chart of the Small Reaction Turbine containing eight runner seriations is shown in Figure 1. In this figure, the upper left part is adjacent

to the chart of the reaction one and the lower right part is adjacent to the impulse one, and a unitary type chart is formed by linking the above mentioned parts. The small type chart consists of two parts, i.e. seriation less than 500 Kw and table of the selected types from 500 Kw to 10000 Kw.

500 Kw seriation contains eight runners models and 32 varieties, which is arranged and finalized from more than 90 varieties which have been designed and produced. The seriation contains water head within the range 2 - 270 m, the flow within range 0.07 - 8.6 m^3/s, the output within the range 16 - 630 Kw (see Fig. 2).

In order to realize the unitary type of the structure, the axial flow one contains two runner models and ten varieties, and all adopt the simple structure of vertical open flume. The general open flume is adopted for 2 - 4 m, while the pressure open channel for 7 - 14 m. Fixed blades are used for runners. For less than 60 cm of them, monoblock casting should be adopted. The easy adjusted and installed inner single ear control ring, and as water-leading bearing are adopted in the set, horizontal arrangement, metallic spiral casing, two supporting points of the main shaft and hanging control ring are used for the mixed flow one. In order to reduce the process allowance, two supporting points guide vanes are also adopted. The impulse type turbine consists of three models (including the Pelton and the inclined jet impulse one, etc.) and ten varieties with single jet matched with bend injection pipe. A great number of standard parts and interchangeable parts are used. They amount for 80% of the total parts, such as the sliding bearing, rolling bearing, flywheel and elbow draft tube which posess several specifications. The centre height of the units and the inlet diameter of the spiral casing are standardized, they can be adopted with standard valve. The unity of general layout and external installation dimension creates a favourable condition of the plant house arrangement finalization of the hydro power station. As the standardization, seriation and generalization are extended vigorously, the units get improved in the quality and decrease in the costs. So the prices of the Chinese units are cheaper.

Fig. 1 - Application range of small, medium reactive turbine

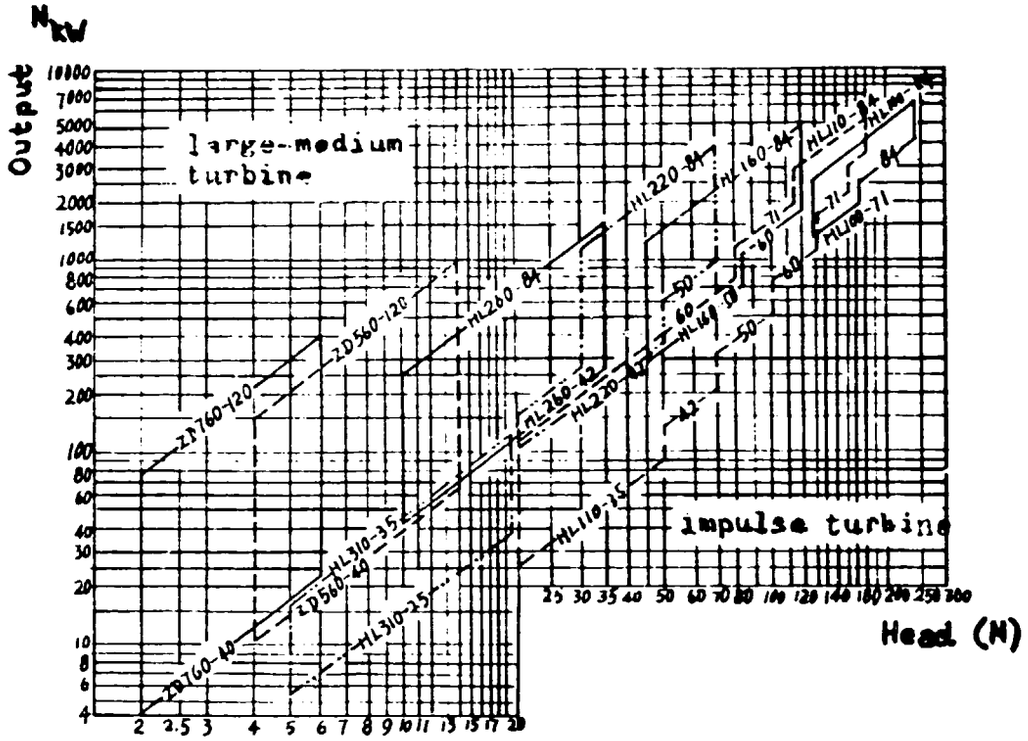
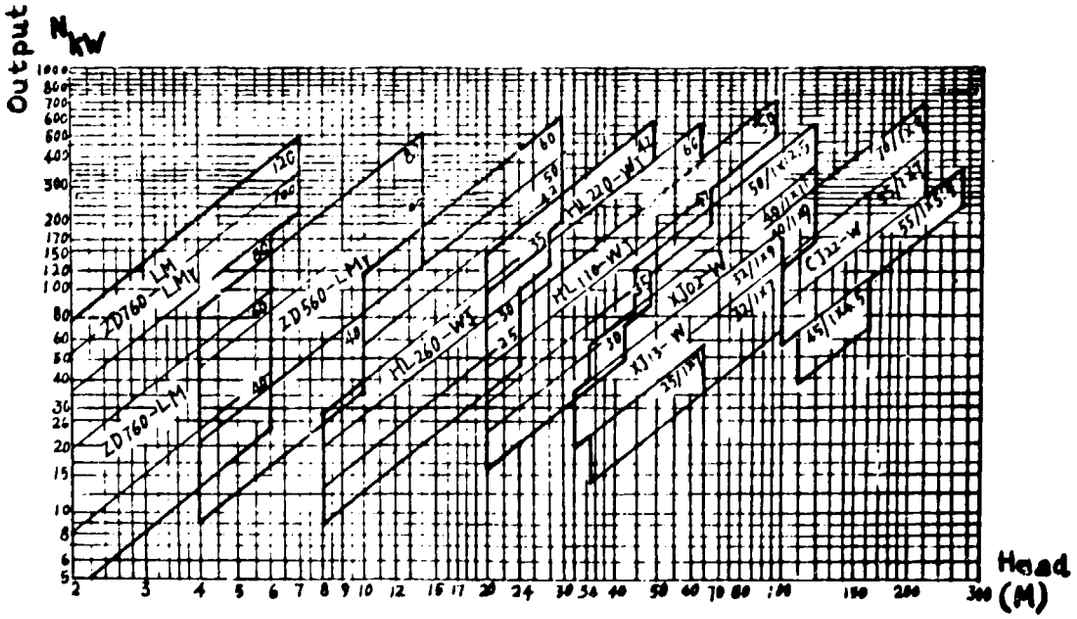


Fig. 2 - Product series of hydro turbines below 500 Kw.



The selected type chart from 500 Kw to 1000 Kw contains 38 varieties selected through extensive investigation for hydro power stations on the base of the hydro turbines produced and 15 varieties redesigned in order to fill a vacancy of the chart. There are 53 varieties in total, including the mixed-flow, axial flow (propeller or Kaplan), impulse as well as tubular (fixed blades or adjustable blades) and 19 runners models. This chart is suitable for water head within the range of 3 - 450 m, for flow within 0.26 - 205m^3/s (see Fig. 3). These serve as sorts to be developed in the Fifth Five-Year-Programme and the Sixth Five-Year-Programme.

Generator seriation

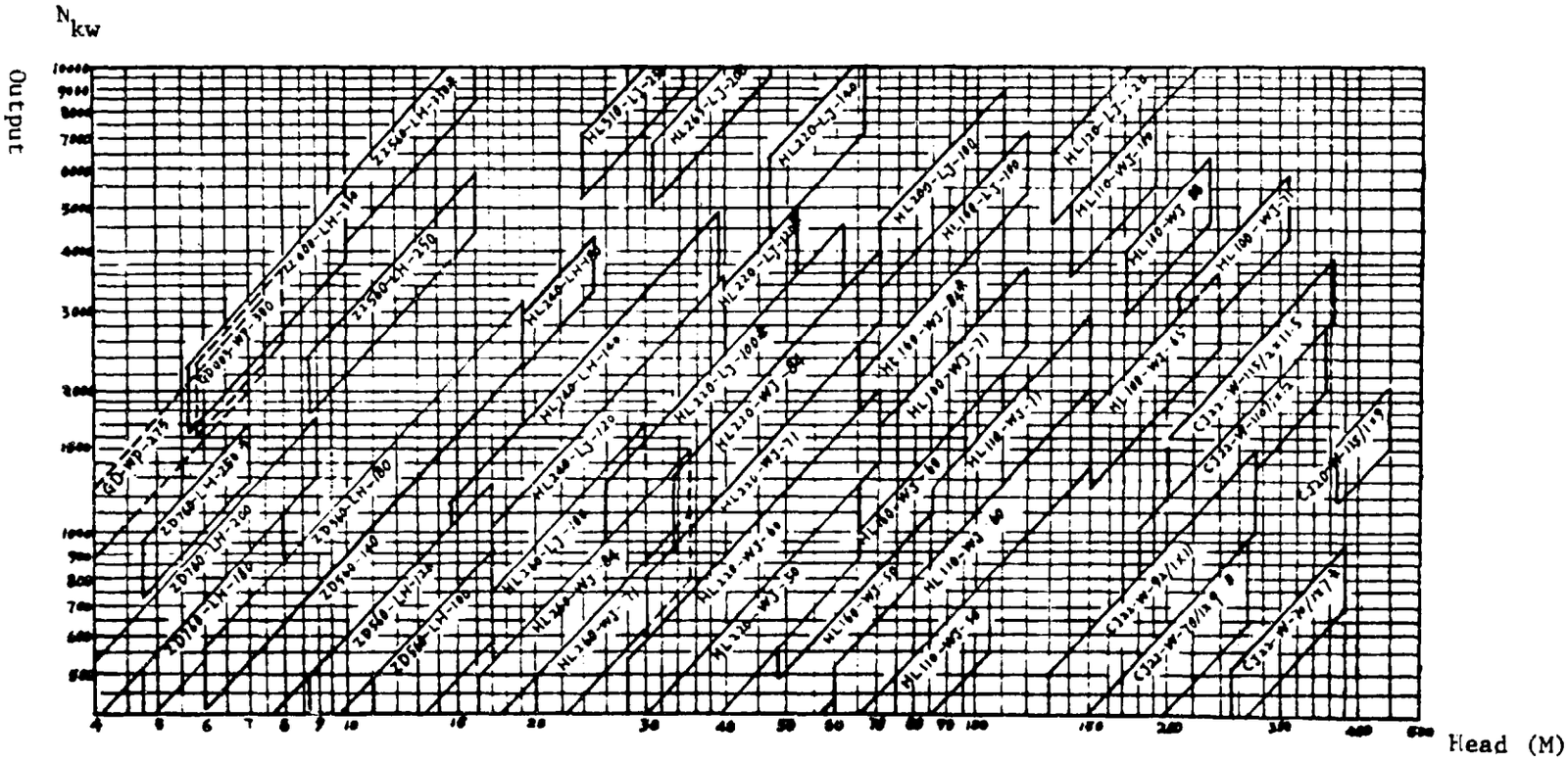
In China, the small generators using synchronous one have been designed for seriation. The coefficient of increase by degree 1.25 is adopted for capacity from 200 Kw to 630 Kw and 500 Kw to 5000 Kw, the capacity grades are of 100, 125, 160, 200, 250, 320, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3200, 4000 and 5000 Kw; the mini capacity grades are of 12, 18, 26, 40, 55 and 75 Kw. Only the revolution of a few mini capacity is 1500 rpm. The revolution of seriation is mostly 1000 rpm. In every generator support has two to four cores length and every core length is arranged with several kinds of revolutions. The two voltage grades of 400 V and 6300 V are adopted in China. When the unit is below 500 Kw, it is generally 400 V called low tension one, however, there are exceptions. The asynchronous generators are produced in China and can be supplied for other countries. At present, the new 50 Hz generator seriation of 100 - 800 Kw which are in the planning process are tentatively arranged with 5 supports and 49 varieties.

Auxiliary equipment

1. Speed governor

The mechanical-hydraulic speed governor is adopted widely, its grade of capacity covers 35, 75, 150, 300, 600, 1500 (1800) and 3000 Kg.m. For its performance and parameters, refer to Table 1.

Fig. 3: Product Specifications of Turbine Generator Within 500 - 10000 Kw



Note: 1. "meter" means new products

2. Tubular turbine generator as shown in the dash-line blocks are undecided products.

Model TT is a one stage amplifying governor in which the pendulum drives the guide valve to control directly the piston of the servomotor, and controlling oil which comes from the oil pump. Model YT is a two stage amplifying governor in which the guide valve can be used to control the piston of the servomotor through the main distribution valve. This governor possesses high reliability, high automization level and tele-control. Model YDT - 1800 is an electrical - hydraulic governor.

2. Intake valve

The gate valve, butterfly valve and ball valve are in common use. For their main varieties see Table 2. The gate valve is used for medium and high head with small size. Its feature is of large opening force, long closing time and less leakage when fully closed. The butterfly valve has small opening force with easy and fast operation. It can be used for larger diameter one and be automatically operated. The ball valve is operated generally by hydraulic pressure. It needs less force and can make close seal from water. It has less hydraulic loss after full opening and can bear high pressure, so it is suitable for high head. The heavy hammer butterfly valves are used for emergency close, so that the remote control can be realized.

3. Excitation device

In the past, direct-current exciter was in common use. At present, the semi-conductor exciter is used, in which the alternative current is converted into direct current by the thyristor or rectification elements for excitation of generator. According to the source of alternative current, the excitation device can be divided into three kinds: double winding shunt reactance, phase compound and harmonic excitations. The same type of generator can be fitted with several excitation modes in accordance with the condition of a manufacturer. The double winding shunt reactance is generally used for 49.3 generator support; the double winding rotating rectified brushless excitation and static excitation system with supplying transformer are used for that of 59 - 99 generator supports. In addition to use the direct current exciter, the static SCR compound exciter and thyristor excitation system are adopted for that over 99 generator supports.

Table 1 : Mechanical-Hydraulic Speed Governor

Model	Type	Working capacity power (Kg.m)	Closing time (S)	Max. rotation angle of regulating shaft (degree)	Permanent speed droop (%)	Speed regulating range (%)	Temporary speed droop ( )	Time constant of the damping device (S)	Driving mode of pendulum
TT-35	single regulating throughflow	35	3	45	0-6	±10	0-80	0-15	asynchronous motor
TT-75	do	75	3	35.4	0-6	±10			Belt
TT-150	do	75-155	2.5	45	0-6	+10 -15	0-80	0-15	asynchronous motor
TT-300	do	140-300	2.5	45	0-6	+10 -15	0-80	0-15	do
YT-300	single regulating pressure oil tank	155-300	2	45	0-8	+10 -15	0-100	0-20	do
YT-600	do	315-600	2	45	0-8	+10 -15	0-100	0-20	do
YT-1020	do	525-990	2	45	0-8	+10 -15	0-100	0-20	do
YDT-1800	do	960-1800	2	45	0-8	+10 -15	0-80	0-20	do
CT-40	do	2500	2	45	0-8	+10 -15		0-20	synchronous motor

Table 2: Intake valve

Name	Varieties of manual operated (cm)	Varieties of electric or hydraulic operated (cm)
Gate valve	125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700	300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200
Butterfly valve	400, 450, 500, 600, 700, 800	400, 450, 500, 600, 700, 800, 900, 1000, 1200
Ball valve		125, 150, 200, 250, 300

Founding factory on self-reliance

At present, there are nearly one hundred small hydro equipment manufacturers in China. In the early stages of their construction, some of these manufactories were either state-private, agricultural machine or for repair and spare parts, or were experimental factories of schools etc. These manufacturers were rather small with simple and incomplete equipment. In line with the spirit of hardworking and self-reliance, they were manufacturing while building working houses. Some of the house roofs were of wood and tile structure, some wall bases were constructed of indigenous rock, and some were made of indigenous materials such as stores. Thus not only saved investment but also guaranteed the building process. During construction, when the hoisting equipment became insufficient, they made simple chain block and chains in order to install the large post and ridge beam. 3T and 5T hoist in the workshop were designed, manufactured and installed by themselves. As the wood is distributed by the state, it is not easily available for urgent use. They solved this problem by using some substitution, for example, through the use of indigenous mould instead of capital construction plate of wood mould. The cable channel underground of the workshop was made of prefabricated concrete, when the steel pipe was in short supply.

Table 3: Capital Construction Conditions for a Factory to Produce 500 KW

Ser. No.	Name	Area (M^2)	Unit	Application
1	Metalworking shop	1500	1	For making the unit assembly and parts
2	Metal cold working shop	600	1	For cold making of the spiral casing, draft tube, inlet and outlet elbow pipes and expansion joint
3	Forging shop	400	1	For forging the parts
4	Foundry shop	400	1	For shaping and casting the parts
5	Repair shop	300	1	For repairing small, medium and large tool machines
6	Transformers shop	150	1	For transmitting and transforming electricity

With the spirit of hardworking and thriftiness, they applied waste material and products to make full use of limited fund. Table 3 shows the condition of capital construction of the factory for producing 500 Kw set which contains the essential workshops of making, welding, assembling, steel plate processing and casting.

According to the available condition, they manufacture some equipments when they are insufficient, such as Rushan Machine Works in Shandong Province which made a indigenous lathe with reinforcement concrete construction base to replenish the machining capacity of lathe at that time. Linhai Machine Manufacturing Works in Zhejiang Province made a indigenous vertical lathe which was composed of metal guide and concrete construction post and pedestal.

This kind of vertical lathe mentioned above could be almost made by every factory in order to meet the needs of machining at that time. The higher authorities assign some sophisticated equipments such as grinder, borer and punch to form a complete set. If the capacity of cast furnace is not sufficient, they make a new furnace even for a single element, that is, to adopt a temporary emergency measure to complete the casting. After products have been produced and sold, the plant capital was only recouped and the factories could be replenished with a few new equipment in order to accomplish the expanded reproduction. With the profit and investment recovered, the factories which were stagnant could be developed continuously. Table 4 shows the general equipment for a manufacturer producing 500 Kw units. Bailian River manufacturer is a small factory which occupies an area of 16000 m^2, which can produce 3000 Kw units. The total value of the state investment has been more than five hundred thousand yuan since the construction of the factory in 1970. During the 11 - 12 years, the factory has produced more than 1200 units of generators with different capacities amounting to 90000 Kw, and produced more than 160 units of hydro turbines. It has turned the profits of 8,800,000 yuan over to the state in these years. This profit is equal to 1.7 times that of the total state investment. This way of building a plant shows advantages of less investment but quick benefits when it is compared with the common way of "a large sum of investment paid at one time for building a plant and production after its completion after several years". Therefore, the former is in line with the economic conditions of the developing countries.

Having national manufacturing equipment in mind

All the equipments in operation of 88000 SHP stations are made in China. In many key parts of the set such as main shaft, spiral casing, runner, guide apparatus, stator, rotor, etc., there are complex technological processes and high technical claim. From the wood model, the manufacturer carries out moulding, casting, workpiece machine,assembling and adjusting to the installation of the station. There are a lot of heavy works in production and generating. First of all they depend on the available machining equipment such as lathe, miller, planer grinder, cast welder to arrange

Table 4: Universal Equipment Required for 500 KW Units

Ser. No.	Name	Specification (mm)	Unit	Application
1	Vertical lathe	2000	2	Machining for runner at low head, spiral casing, head cover bottom ring generator support, magnetic yoke
2		1250	2	Machining runner, control ring and other parts
3	Horizontal lathe	ϕ 400x1000	2	Machining parts less than 1m length
4		ϕ 1000x3000	1	Machining main shaft and parts less than 3m
5	General horizontal lathe	ϕ 90x200	15	Machining small parts of the unit
6		ϕ 400x1500	1	Machining parts less than 1.5m
7		ϕ 320	10	Machining small parts of the unit
8	Upright drill	ϕ35	1	Drilling and boring for the parts of unit
9	Beam drill	ϕ25	3	Drilling and boring for the part of unit
10		ϕ25		
11	Bench drill	ϕ15	6	Drilling small holes for the parts of unit
12	Borer		1	Boring for spiral casing and generator support
13	Circular grinder	ϕ200x500	1	Working the die of the stator and rotor of generator
14	Surface grinder	300x1000x400	1	Working the die of stator and rotor of the generator
15	Vertical miller		1	Milling the key slot of the parts
16	Planer	650	3	Planing the parts

Ser. No.	Name	Specification	Unit	Application
17	Hydraulic planer	900	1	
18	Double-housing planer	2000x800	1	
19	Punch	30t	3	Machining the silicon steel of the generator starter and rotor
20		60t	2	= " =
21		100t	1	= " =
22	Press	100t	1	For shrinkage of the main shaft and magnetic yoke and other parts bending
23	Plate bending rolls		1	Bending for the spiral casing, draft tube
24	Hoist	10t, 5t, 3t	each 1	Hoisting in the process of general assembling and parts machining
25	Furnace	1.5t	1	For founding the parts
26	Air hammer	150kg, 250 kg	each 1	For forging the parts
27	Electric welder		5	For welding
28	Testing equip-ent of the generator		1	For general assembling of ·nit, testing parts and performance of generator
29	Soft shaft wheel		5	Grinding the through-flow surfaces of the run-blades, the guide vanes and spiral casing

machining according to the technological process. It can be satisfied by improving the machining method under the guarantee of product quality and performance as required. For instance, HL 240 - LH - 14 micro self-contain set manufactured by Fengxin Machinery Factory in Jiangxi province has a mixed-flow runner which has only 14 cm diameter with very thin blade. If the common process is adopted to cast the runner, the reject rate will be high. Because the blade is in small size, it's hard to polish and its smoothness can hardly be up to the requirement. So, precise casting is adopted. The 100 Kw tubular turbine set trial produced by Gurlin Machinery Factory in Guangxi province has with the maximum external diameter of 2.5 m with fixed space guide vanes. Therefore, it is difficult to cast it integrally. After consideration, cast steel vanes are used instead, and both the internal and external rings are shaped with steel plates. Finally it is shaped into integral by means of welding. The movable guide vanes of the tubular turbine are of space moulding line too. It is required that water should be sealed when closing the guide apparatus. Through calculation, a special kind of moulding device is designed by the manufacturer, thereby it is insured to meet the requirement in machining. Small type of spiral casing applicable for not very high head can be either welded or cast to the given strength. As for welding or casting the manufacturer may select either of them according to its condition. The draft pipe and its conical section are shaped with scraping plates, which can save a great number of wood moulds. The elbow tube can be also replaced by an equi-circle section. It can be shaped with scraping plates, which is much more simple. As for the newly founded factory co-operation from outside ot it may be obtained. For instance, the spiral casing can be cast by a foundry factory. The main shaft can be supplied by special foundry factory, however, the parts which need high precise machining may be entrusted to the specialized factory for machining. For example, the planetary gear of the tubular turbine in 1960s designed by Tianjin Research Institute of Electric Driving and manufactured by Tianjin Electrical Equipment Works was supplied by a large plant in Harbin. Since the runner is the heart of the turbine, its size and type as well as opening, making etc., demands high precision. The runner of the inclined jet turbine produced to be exported by Yueqing Machinery Factory in Zhejiang province has a stainless runner of 50 cm in diameter.

As space size is small and characteristic of welding the stainless steel is poor, the factory can not solve this problem in short time and has to ask the special welding unit to settle it. The speed governor is produced by a professional factory and the conduit valve is made in universal valve works, even purchase orders can be made directly. The interchangeable parts such as electric elements, bolts and nuts etc. can be directly purchased on the market. When the larger unit is trial-produced, more co-operation with other factories should be taken, however, once batch process has been engaged, the main parts are machined in the plant. If special requirement is needed for the fittings, it is likely to use the specialized equipment for machining. So that the accurate coaxiality of the head cover with the staying ring is required, the professional borer should be used. The shaft of the generator should be shrunken on the magnetic yoke as a whole by the shrinker. The coil of the generator is wound by the winder, and assembly-welding for the runner is done via assembly welding device. The special equipment can carry special machining only. Normal machining is finished by the self-made equipment in the factory in accordance with the size, shape and technological requirement of the fittings. The special equipment for machining 500 Kw set is as shown in Table 5. The parts should be tested in the factory, such as the trial operation for bearing and the hydraulic pressure test, for spiral casing, the withstand voltage insulation test for the generator and the static balance test for its rotor. All of the equipment for tests will be gradually provided by the factory itself.

The given holder, clamp, mould, jig and measuring tools, especially used in large workpieces should be completely purchased while specific one should be produced within the factory. It is profitable to raise the technical level of the factory to undertake technical innovation and learn the relevant experiences from those of the same trade.

The trade work and seriation design carried out by the management department.

The personnel familiar with this technology, were organized to design the typical products by using the limited information available about the hydro turbine generator set from abroad. The experience obtained was improved through trial manufacturing, then seriation products were designed and the design diagram were directly distributed to each plant.

Table 5: Special Equipment for the Units 500 KW

Ser. No.	Name	Unit	Application
1	Boring equipment for head cover and bottom ring	1	Boring for head cover and bottom ring at the same time
2	Special borer	1	Machine for the spiral casing
3	Runner balancing equipment	1	Balancing for the runner of the turbine and the rotor of the generator
4	Centrifugal casting machine	1	Casting for bearing metal
5	Winder	1	Winding for generator coil
6	Flat winder	1	Winding for the flat copper wire of the rotor coil
7	Paint rating equipment	1	Paint rating for the generator
8	Withstand voltage test switchboard	1	Withstand voltage testing for the generator insulation
9	Borer	1	Boring the main shaft and the flywheel at the same time
10	Reamer	1	Reaming the flange holes of the main shafts and generator at the same time
11	Shrinage equipment	1	For shrinage of the large shaft and magnetic yoke
12	Runner welding assembly device	1	For welding and assembling the runner

So long as a factory even a new one can get some technical guidance, blank (semi-finished product) will be prepared according to the diagram to organize machining. The quality of a product is checked according to the technical documents (such as Specifications of Technical Conditions for Through-Flow Parts), finally put into operation at the station and experiences obtained. Thus the qualified personnel has been trained as well as the products have emerged during the process. The department responsible for the trade will eliminate the backward products of the runner and complement quality. For the seriation design of below 500 Kw turbine, it amounts to 86000 sets in the whole country. There are very rich experiences in manufacturing and operation. For this reason, 20 or 30 professional units are specially organized and centralized to improve the design. The backward HL 240 seriation and pot-form ones are removed in the process of reorganization. And through standardization, seriation and generalization, the products have been improved a lot.

Such as Technical Condition for the Through-Flow Parts announced in 1980 (see Table 6), in which the original design standard is hightened, reflecting the manufacturing level of our country is raised. Most of the standards are equal to but a few surpass the world standard, made by the International Electricity Committee. That will further promote the factories to improve the quality of products, make a public appraisal of the quality of different products, and sum up the advanced experiences in various factories and spread them among those of the same trade so as to raise the technical level.

Continuously raising automization level in the light of specific conditions in China.

In the early days, because of the limitation of the technical level, only simple units were produced such as the axial flow which were all of propeller structure with direct exciter (no speed governor). It was operated manually by holding the handwheel of the guide apparatus, as a driver, constantly regulating speed in accordance with electricity consumption charging. Voltage will be regulated by manual excitation rheostat, when the operator saw the indicator lighting up.

Table 6: Inspection Unit and Allowable Error of Tunner's Through-Flow Parts of Mixed Water Turbine

Inspection	Unit	Original standard	New standard	Modification No.1 of 193 Inter Electricity Committee standard
Inlet angle	single valve average valve	no inspection	$\pm$ 3% $\pm$ 1.5%	$\pm$ 3% $\pm$ 1.5%
Section shape of inlet	model length allowable error	no inspection	$\pm$ 0.1 D_1 $\pm$ 0.1% D_1	$\pm$ 0.1 D_1 $\pm$ 0.1% D_1
Head shape of inlet	model length allowable error	0.03 D_1 unspecified	0.03 D $\pm$ (0.05% D_1+0.5mm)	
outlet angle	single valve average valve	no inspection	$\pm$ 2% $\pm$ 1%	$\pm$ 2% $\pm$ 1%
Section shape of outlet	model length allowable error	no inspection	front 0.1 D_1/back 0.15 D_1 $\pm$ 0.1% D_1	front 0.1D/back 0.15D $\pm$ 0.1% D
Thickness error side	in outlet	unspecified	+0.5 mm/ -20%	
Shape	model length allowable error	0.03 D_1 unspecified	front 0.02 D_1/back 0.04D_1 $\pm$0.05% D_1+0.5 mm	No
Opening	single average	$\pm$0.25% D_1 -0.15% + 0.2% - 0.1% D_1	+(5% a + 0.7 mm) -(3% a + 0.7 mm) +(3% a + 0.5 mm) -(1% + 0.5 mm)	+ 5% - 3%[a] + 3% - 1%[a]
waviness X/U		no concrete stipulation (unallowable hollow and convex)	common part 2/100 easy cavitation part 1/100	common part 2/100 easy cavitation part 1/100
Blade thickness		+ 0.002 - 0.001 D_1	no	no
Blade pitch	(P)	$\pm$ 0.4% D_1	$\pm$ 0.4% D_1	$\pm$ 5% D

Though it was complex, its construction was simple, easy in maintenance and management, and cheaper in price. This tallied with the technical level at that time and settled the electricity problem. This was acceptable for the users. However, when higher automization units were installed in some stations in the remote areas where the technical level was comparatively low, some trouble unavoidably occured such as stopage of operation for maintenance due to shortage of spare parts in the area after the damage of the electric element. With the dev elopment of production the manufacturer can supply motor or auto speed governor. In late part of 1960s, conductors were greatly spread in China. The conductors were reliable. Auto modulation and the voltage regulation devices are in wide application. As all the parts can be purchased at home, there are rigid base for raising automization level. The automization level has been continuously raised. The through-flow type speed governor used in early years was improved still more last year. It is named Model TTA which was now put into production, prov iding for users at home and abroad. The load controller for power supply of the run-off-river stations has simple construction, low price and excellent characteristic of stable frequency. This kind of balancer has been developed by 5 or 6 manufacturers in our country, and have been put into production in 1 or 2 factories. The unit monitoring and testing meters such as cooling water flow indicator, bearing temperature and generator temperature indicators as well as auto braking device are supplied as complete set of below 500 Kw so as to make it possible for the station to realize supervision.

Recommending to use national resource and materials

Under the guarantee of the unit quality, the national materials and products should be selected as much as possible, therefore, it cannot only develop the national industry but also decrease costs. In early years, wooden hydro turbines were used in China. Porcelain runner was produced in porcelain developing area. Sichuan province used steel concrete to manufacture hydro turbines so as to confo with the local level and requirement and played a historical role in hydroelectric enterprise. The copper is of the restricted material which is seldom adopted in design diagram. The copper

wire can be replaced by the aluminium wire to make aluminium wire generator for common customers. The copper brush can be replaced by local superior wood brush or nylon brush. In China, nickel (Ni) and chromium (Cr) are of rare metal, its anti-cavitation is more excellent than the conventional carbon steel. The Chinese technicians bravely welded stainless steel plate with the runner blades and inlaid the stainless plate on the through-flow meter of the guide apparatus. Thus the cavitation performance was ensured. Wood and steel pipes serve as the penstock for the SHP station, even bamboo pipes were adopted in some stations. In recent years, prestressed cement penstock has been introduced. Huangtong River Hydropower Station has water head of 8 m, which was installed with 3 sets of 800 Kw. Its penstock with 60 cm in diameter was made of local sand and stone so as to save rolled steel and cost. It is worth attaching importance to these experiences.

Promoting to raise the manufacturing level scientific research

In China, there are several research institutions established with hydro electric equipment. The Asian and Pacific Regional Centre for SHP established in 1981, is in charge of the training and information in the region. It also undertakes certain scientific research. The relevant universities and colleges also undertake research for SHP. There have been about ten test bases throughout the country. The plants with rich experience such as the Chongging plant set up the hydraulic test station early. There are much more generator-laboratories. These organizations have quite a number of scientific research personnel who have done successful research work. Great achievements have been obtained in studying runners. Type ZD 560 HL 100 and ZD 760 etc. qualified runners have been created, of which ZD 760 was developed in the Jinhua Hydro Turbine Works by means of self-made test station. Achievements had been obtained in small type tubular turbine study at the end of 1960s. The efficiency of 250 cm model is upto 90%, which has been used in 500 Kw units at tide power stations. Small axial extention turbine also has been produced in China. Micro self-contain turbine generator set of 100 Kw below, produced in China, is simple in construction, convenient in maintenance, suitable for remote and isolated rural areas. Quite a few of them are supplied abroad. Modification and improvement of the products will be undertaken.

In research of the speed governor for the impulse turbine, great improvement is paid to the traditional co-ordinated method of nozzle needle and deflector, and its performance of frequency modulation is stable.

Recently, it has been evaluated and prepared to put into production. The regulating valve is considered to be used instead of the conventional surge chamber, so as to save steel, wood and cement. This achievement has won a National Prize of Science and Technology. Science research is beneficial to development of hydroelectricity.

China pays great attention to the development of SHP. Since the variety of the resources, rich experience in manufacturing various units, the most important experience in China is to establish manufacturing capability on self-reliance.