Framework Design of Incentive Policies for Small Hydropower Development in China

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Policy is an important administrative measure for promoting small hydropower (SHP) development in China. At present, the critical topics to be studied and solved urgently are: to find out questions and reasons that constrain SHP development upon investigation and analysis of policy environment of macro-economy and techno-economic indices of SHP development, and to hammer out the policy framework and operation mechanism complying with the requirement of market economy, enabling the sustainable development of SHP.

I Technical-economical feasibility analysis for SHP

In China, SHP is defined as stations with installed capacity up to 50MW. SHP technology is mature and proven. Its major features are as follows:

1. ***Rich resources.*** The exploitable SHP resources in China is 87 million kW (as per the general investigation of hydraulic resources in 1980s) which occupies 23% of total hydropower resources in the whole country and stands top in the world.
2. ***Widely spread.*** The exploitable SHP resources are widely spread over 1,573 counties in the nation. There are 58.28 million kW in west China, occupying 67% of the country's total exploitable one; 28.72 million kW in central and east China, 33% of the same. The allocation of SHP resources is more widely dispersed than other energy resources such as coal, petroleum and natural gas. In particular, it has better accessibility and affinity to local economy in west China.
3. ***Flexible development.*** SHP could be separately developed, could formulate local grid and supply electricity dispersedly. The capacity developed could be several, several tens, several hundreds up to several tens of thousand kW according to demand. It is capable of providing power to household, village, township (town) and county (city) and has very strong adaptability and capability of radiation. In addition SHP is of small scale, needs comparative less capital investment, with mature technology, short construction period, fast effective, easy maintenance and low operation cost. It is more technically and economically feasible to construct SHP than to develop large and medium hydro and thermal power in economically poor regions. It should be pointed out that it is most appropriate for local government to organize the SHP development while the central government is focusing capital for large power generation projects.

SHP has attained rapid development in China due to its significant function in solving rural energy supply, improving ecological environment, alleviating poverty and promoting rural economic development. Since 60-70s of last century, the supply area of rural hydropower has gradually expanded to cover nearly 1/2 of the whole nation's territory, with 1/4 of the whole nation's population. Number of SHP stations completed is about 40 more thousands with installed capacity of 26.26 million kW and annual generation of 90,000 odd Gwh, occupying 30% of total consumption in rural electricity market in the country.

Remarkable economic and social effect has been achieved through development of SHP. Currently, SHP has acted as vital support for socio-economic development in hilly areas in central and west China. It drives the urbanization and industrialization through electrification and also promotes the regulation of economic structure. Following the prosperity and continuous development of local economy, steps of poverty alleviation were speeded up, rural energy consumption solved, ethnic solidarity strengthened and stability of border areas promoted as well.

Especially, in providing electricity to basic public service sector for people in remote area un-accessible to electricity, SHP possesses evident advantages and has been consistently playing the un-replaceable role. The construction of rural 653 hydro-based primarily electrified counties during "7th, 8th and 9th Five Year Plan" not only solved the electricity supply to 120 million people not accessible to electricity but also widely and greatly increased the rural electricity consumption level in the respective areas. At present, there are still 30 more million people not accessible to electricity, more than half of them are distributed in the regions with rich SHP resources. The geological position of these areas is extremely remote, with dispersed low load. It is not practical to provide electricity through extension of national grid to these areas. Therefore, SHP will continuously play the important role in the final fortifying storm for resolution of non-electrified population.

The ecological effect of SHP is also excellent. Currently the total annual generation from SHP in China is equivalent to 30 million tons of standard coal. Its ecological effect is equivalent to preventing 70 million tons of emission of greenhouse gas as CO_2 and large amount of flue dust and polluted water. Development of SHP could create fundamental criteria for replacing fire wood by electricity in providing energy for living and for agricultural processing. Replacing firewood by electricity reduces deforestation in SHP supply area. Evident results of hill blocking and forest raising and returning farmland to forest was attained, as the percentage of forest coverage increased year by year. Water resources were reserved and soil erosion prevented which caused the fast recovery and improvement of ecological environment.

II Analysis of present status of SHP policy environment

In comparison with exploitable SHP resources in China, the percentage of exploitation is rather row, only around 30%. Reasons for this slow development are resulted from weakness of SHP itself and external economic policy environment, etc. It should be pointed out that the macro economy policy environment for energy is not favorable to SHP development. SHP has been developing through a rough and bumpy road onto the present mainly due to initiatives of developing local economy from local government. This signifies its good external economics but could hardly ensure its internal economics and benefit of its own thus lacks the mechanism of sustainable development.

For promoting SHP development, a series of supporting policies were stipulated by central and local government during various development period of SHP. According to their nature, these could be classified into administrative compulsory type (AC), economic incentive (EI) type and market creation (MC) type. Relevant stipulation of SHP in the Law of Electric Power belongs to AC type policies. The strategy of “self-construction, self-management and self-consumption” for rural SHP formulated by the state belongs to MC type policy. The EI type polices include: (1) policy of profit of SHP reserved for further expansion of SHP; (2) permission of utilizing nation’s poverty release capitals for construction of rural SHP; (3) policy of 6% value-added tax for SHP; (4) policy of specified loan for SHP development (dismissed).

These prevailing policies takes policy of economic incentive based on planning economy as major one, but rarely related to basic element of market economy, i.e. price and relation of demand and supply. The function of market mechanism has not been reflected fundamentally. The AC type policy also did not make any stipulation for qualification and quantification of SHP. Especially, it lacks concrete subsidiary policy and operational function relating to the right of integration into the grid and volume to electricity. The MC type policy, though came up rather earlier and had touched the issue of property right, is much imperfect and could hardly be executed under various complicated factors of the nation’s reformation for economic institutional system. In the EI type policy, only regulation function of tax and subsidies were focused while the disposition function of capital by the market element-price was not fully utilized. The SHP as a public welfare sector, has actually been drifting with the tide in the tough market competition due to abolition of specified loan, limitation of financial subsidies and non-execution of 6% value-added tax policy in most regions. SHP will exert even more impact in the “separation of plant and grid, competitive price for sales to the grid” policy from the reformation of power institutional system, if necessary protective measures were not adopted. In a word, the significant reasons for the slow development and difficult walking of SHP were its divorce from policy support of the government. At present, the SHP development urgently needs to gain a foothold on new incentive polices under market economy condition.

III Problems existed in the marketing operation of SHP

For SHP development, the internal unfavorable factors of itself are: small scale production, consistent increase of capital investment, contradiction of seasonal variation, low level of technical equipment and operation and management, etc; in the meantime, there are also external impact such as difficulties of selling electricity, unsmoothness of price mechanism, slow development of market, constraints of its public welfare character, etc. Within all contradictions, the most critical ones are small scale generation, difficulties in selling, seasonal variation, price mechanism and constraints of its public welfare characters. These have directly affected the economic effect and competitive capability of SHP and resulted in the low capital return rate, difficulty of financing and lack of capability for sound cycle rolling development.

1. Small scale generation

The common problems facing commercial operation of renewable energy are: relative narrow market for renewable energy and comparative high capital investment caused by small scale production, and in turn, comparative high energy production cost derived from low volume energy production. SHP is of no exception. Under present macro economic policy environment for energy, SHP mostly with installed capacity less than tens of MW would no doubt be in an inferior position in competing with large conventional power plant with capacity of several hundreds MW and even several thousands MW.

2. Difficulty of selling out

Due to different affiliation of SHP and national grid, the problem of integration of SHP into the grid could not have been solved for long. It would either be uncapable of integration or with very low electricity price in connecting to the grid, thus decrease the profit of SHP and increase the risk of investment.

3. Contradiction of seasonal variation

Most SHP stations are run-of the-river type in China, which lack the capability of regulation. During raining season, SHP would have large volume of spilling water due to surplus power in the grid; while in dry season, shortage of electricity would occur in the grid. This is also one of important causes for cost increase for SHP.

4. Unsuitable of price mechanism

Formulation of electricity price for SHP lacks standardized policies and regulations. Stipulation and regulation of electricity price bears considerable subjectivity and randomness, and lacks scientism as decision were usually made by work experience, enterprise status and understanding of future tendency of national policies of decision makers themselves. In addition, the structure of SHP price does not include rational reward of its external economic factors. The current price level of SHP not only deviates from the law of value but is also not able to reflect the relation of demand and supply. This is not favorable to dispose natural resources through market and severely affects the survival, consolidation and development of SHP.

5. Constraint of public welfare character

Quite a lot of SHP projects were constructed in conjunction with water conservancy project, with comprehensive function of flood protection, irrigation and water supply etc. in addition to power generation. Spilling water in flood season, as well as irrigation and water supply would all affect the generation. SHP has to spill water and empty the reservoir in advance for protecting the flood disaster. It also usually raises water level reverse with normal seasonal demand for ensuring industrial, agricultural and city water supply, thus misses the opportunity for generation; or under long time low head operation resulting in decrease of turbine output and loss of economic benefit. These losses in cascade developed stations would be even greater.

IV Conceptual strategy for incentive policies for SHP

The design of incentive policy for SHP is a complicated system engineering. In the policy framework design, not only background of national macro economic policy should be taken into consideration for finding out the major factors that affect its development through comprehensive analysis and evaluation of its internal and external economic characters, but foreign successful experience should also be absorbed to introduce the market mechanism into the system of incentive policy for SHP. In addition, as SHP possesses the feature of clean energy and ecological environment protection, environmental economy policy should be coordinated during stipulation of SHP policies. This is for ensuring the mergence of policy with relevant sectors for the purpose of enhancing entirety effect of economic system.

At present, the average specific construction cost for conventional energy large thermal power plant is 4000-5000 Yuan/kW; that for SHP, 6000-8000 Yuan/kW; and that for wind power generation 9000-12,000 Yuan/kW. The average specific energy cost for conventional energy large thermal power is 0.20-0.30 Yuan/kWh; that for SHP 0.30-0.40 Yuan/kWh and that for wind power 0.40-0.50 Yuan/kWh. The economic feasibility of SHP is superior than that of wind power, while it lacks competitive capability versus conventional energy large thermal power.

Typical investigation and analysis for economic feasibility of SHP shows that: generation volume is the major constraint within all factors affecting the benefit and development of SHP. Most of SHP benefit from power generation and supply could not reach the expected value in financial evaluation for the project design. The actual generation volume is the major factor for determining the specific construction cost of electric energy and production cost of SHP. The annual generation utilization hour of SHP in China is evidently on the lower side. Its actual generation volume is greatly lower than the design one and also lower than the effective volume after reduction from conversion calculation with the grid. The reasons for affecting generation utilization hour are closely related to above-stated problems both from SHP itself and from external causes. In addition to factors such as difficulty of electricity selling out, contradiction between rainy and seasons, and constraint of public welfare character etc, there are other factors also affecting the utilization hour, such as year to year and in-year variation of run-flow due to climate change, contradiction between peak and valley load, limitation of load character and repairing and emergency shut down, etc. All these factors have resulted in reduction of actual generation volume from design value at least at 30%, some even over 50%.

Depreciation and interest of SHP are another important factors in determination of specific electricity energy cost ad production cost. Investigation shows that depreciation and interest occupy 19.6% and 31% for average specific cost of SHP respectively. The reason for that is most SHP project are constructed in economically backward remote hilly areas where financial capability is very limited. Therefore the debt rate of SHP is generally high, mostly at about 80%, some even higher than 90%.

The operation cost of SHP occupies 26.6% of average specific cost, in which maintenance, repairing and salary and welfare of staff are of larger portion. This signifies that the level of technical equipment and management need urgent improvement in one side and also that the low profit rate of SHP has caused insufficient financial capacity of enterprises for technical reformation and scientific and technical innovation on the other side.

The fundamental principle to be followed in building up the incentive policy framework for SHP should be: Holding the key line of actual generation volume and other factors that affect the benefit of SHP and setting the starting point of incentive policy on the market basis, purposely utilizing macro control and coordinating measures such as administrative command, economic incentives, creation of market etc, stressed on administrative compulsory policies and function of electricity price to help SHP overcome various barriers and difficulties from interior and exterior.

V Design of framework for incentive policies of SHP

1. Strengthening the administrative compulsory policies

Drawing reference from foreign countries, administrative compulsory policies should be more used in promoting the development of renewable energy which is the weak sector in energy industries during the period of transition to market economy. These policies include quota system and relevant regulations of government at various level. The focal point of the policies should define and quantify the quota and target of development for SHP market, and confirm that renewable energy generation should occupy a definite proportion in local electric power construction. Confirmation should also be made for the priority of integration of renewable energy including SHP onto the grid and full purchasing all the electric energy. This will be favorable to eliminate the unfavorable factors from institutional system that affect the benefit of SHP generation and supply.

The quota system has been proved to be the effective incentive policy for renewable energy in many developed countries. It is recommended that the execution should be accelerated. In the mean time, promotion should be made for the State Council to promulgate the regulation relevant to acceleration of the development of rural SHP, and push forward the stipulation of regulation from local government. For instance, the Decision of Acceleration of Rural SHP Development issued by the Guangdong Provincial Government in 1996 is a local regulation with restraint of law, which clearly defines the priorities of development, of integration into grid, and of purchasing of SHP and its mechanism of price and financial subsidies, etc. The Shanxi Province has also made stipulation relating to production quota of SHP and favorable price for SHP. These local governments' regulations have all promoted the SHP development in their respective places.

2. Stressing the function of resource disposal by electricity price

Severe distortion still exists in the electricity price system in China so far as environmental cost is referred. This is saliently shown in the lower cost of productive raw material of thermal power plants with high pollution. The environment cost resulted from pollution has not been counted into production cost and the environmental space is of free use. Later on, environment factor should be taken into consideration in determining the electricity price mechanism so that the real value of electricity and environment could be accurately reflected, and to establish a price mechanism for sustainable development eventually.

It is recommended that after execution of "separation of the grid and the plant, competitive price in selling to the grid", the protection of market price for SHP onto the grid should be implemented by the government so that SHP will not be directly competed with conventional energy. On this basis, the limit price system of SHP onto the grid with a combination of incentives and restraints should be established. On the one side, price protection for SHP onto the grid with a combination of incentives and restraints should be established. On the one side, price protection for SHP onto the grid should be implemented to subsidize the additional production cost caused by constraints of public welfare and external economic character, thus enabling its rational profit, and on the other side, it is also necessary to push the SHP to continuously reduce its cost and raise its competitive capability. The core of the system is: The government defines the upper limit price for SHP onto the grid, the latter should then be obliged to purchase and not to refuse in case the claimed price from the SHP plant is lower than the limit level. Those SHP plant requesting price higher than the limit will thus be eliminated out of the sector.

In decision of competitive limit price for SHP onto the grid, the model of comparatively mature price system for public service sector in market economy countries like UK etc. could be used as reference. Accordingly, the initial price decision model of limit price for SHP onto the grid could be :

$$P=C*(1+R)+T+V$$

In which, P is the upper limit price for SHP onto the grid set by the government; C is the average social production cost of SHP enterprises; R is the profit rate of the cost; T is officially fixed tax; V is a regulation value considering factors such as demand and supply as well as policies.

The regulation model of limit price for SHP onto the grid is:

$$P'=P[1+(ROI-X)]$$

In which, P' is the regulated price; *ROI* is the index of price of consuming goods; X is the increasing amplitude of labor productivity for SHP.

This method copes with the principle of price decision by combination of incentives and restraints, and could effectively reflect the turn-back to external economic character for SHP and the subsidies to the additional cost resulted from constraint of public welfare character

3. Improvement of tax policy

The policy of 6%value-added tax for SHP should consistently be executed. It should be clarified that for the SHP which does not supply power by transferring from national grid, the amount of value-added tax of the supply sector of the grid shall be checked and ratified according to the principle of making out value-added tax invoice by 6% hand-in and 11% exemption. It could also be implemented in the form of returning after advanced levy to ensure the execution of tax reduction policy for SHP. According to the experience of foreign countries, the tax policy for energy environment should be actively stipulated for collecting the emission payment for environment pollution produced through the energy production process especially those greenhouse gas like CO_2, etc. This collected fund shall be used for subsidies to the construction of clean renewable energy.

4. Strengthening of policy guidance for SHP financing

SHP carries strong public welfare character, and therefore needs support of government with respect to financial budget, channel of investment and financing and credit loan market. A long stable system of investment and credit loan should be set up by the state to enable more capital input into SHP construction. It is recommended that the investment loan for SHP development shall be listed in the financial budget of government at various levels in the nation. The capital from financial treasury will mainly be used for disposal of capital, technical renovation of SHP, quality examination and establishment of systems for after-sale services, etc. The loan for SHP shall be recovered (with maturity over 25 year). Multiplization, multiple channel and multi-direction of major investment part for raising capitals for SHP construction should be implemented through opening up of market, and absorbing investment from the society, foreign funds and private enterprises. This policy is especially appropriate for isolated SHP separated from the grid and operated dispersedly.

5. Creation of SHP market

SHP policy should eventually be set on the basic foothold of the market, the government direct subsidies should be implemented through self-regulated mechanism by fully taking advantage of market element of relationship between price with demand and supply. It should reflect the principle of “who pollutes, who pays; who solves, who be benefited” and formulate the market mechanism with sound cycle of energy and environment development. Following the continuous deepening of reformation of power institutional system market should be actively set up for promoting environment protection and rational development of SHP resources through multiple measures such as division of properly rights, transferrig power to a lower level , privatization, public tendering, licensing, transaction of environmental right, and development mechanism for clean energy, etc.

A Chinese Magazine "Small Hydropower" by HRC

The Chinese "Small Hydropower", a magazine that National Research Institute for Rural Electrification (NRIRE) and Hangzhou Regional Centre (Asia-Pacific) for Small Hydro Power has edited and published for 111 issues (bimonthly), allocated with the International Standard Serial Number ISSN 1007-7642, and China Standard Serial Number CN33-1204/TV. It was published in Chinese and with English titles. Special features are technical experience of SHP development in China. Information of international SHP activities and important events in the field of SHP have also been widely included.

This magazine has carried news, views and articles on all aspects of small hydro power. It is useful to those who are intersted in technical experience of SHP development in China.

"Small Hydropower" is the only professional publication on small hydropower in China, which is issued domestically and abroad. It is widely circled in all corners of China concerning SHP, and getting more and more popular in over 600 rural counties which is primarily hydro-electrified, more than 2,300 counties with hydropower resources, more than 50,000 small-sized hydropower stations, thousands of colleges or universities, research institutes and other administrative authorities on SHP. Advertising is welcome for any equipment manufacturer to target Chinese market on SHP construction, equipment purchasing or other businesses.

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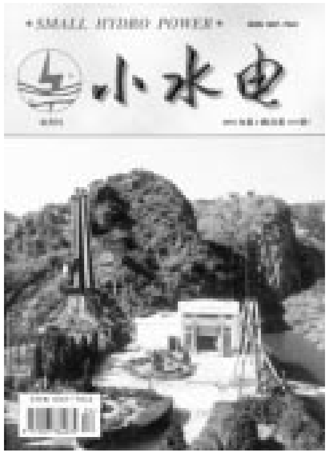

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Some Problems on the technical innovation of small hydropower station

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Abstract: *Main problems on the operation of small hydropower station are listed in the paper. According to practical experience, the author brings forward some problems that should be noticed in technical innovation in small hydropower station, including effective design for the innovation; paying attention to the loss of the water-passage system during reformation of capacity increase of the unit; focusing the work on the innovation of hydro turbine; paying more attention to environmental protection and final acceptance etc.*

Keyword: *small hydropower station; hydraulic turbine; design for the technical innovation; final acceptance*

1. Introduction

The small hydroelectric resource in China is very abundant and the developable reserves reach 71,870MW which spread in more than 1500 countis and cities all over the country. By the end of 2002, over 40000 rural hydropower stations have been built and the total capacity has reached 28790MW which takes the 40% of the developable reserves of the small hydroelectric resource in the country. The total capacity of the small hydropower stations which have been operated for more than 30 years and 20 years is 1530MW and 7570MW which takes 5.3% and 26.3% of the total capacity of the built small hydropower stations respectively. Here is some features of these small hydropower stations: small capacity (often less than 500~3000kW), units, laggard technology, low efficiency, low manufacturing quality, more hidden troubles in safety. Some of these stations have stopped operation, some have completed technical innovation, some are under innovation, and more stations are in urgent need of the technical innovation.

In order to offer some macro guidance to the technical innovation of small hydropower station, including declaration and itemization, design for innovation (consultation), execution, acceptance and management, and to make the innovation more scientific and normalized, the Ministry of Water Conservancy and Electric Power promulgated the professional standard SL 193-97 ***the rules of the technical innovation of small hydropower station [1].*** In recent years, some small hydropower stations had some success, while some problems existed according to ***the rules***. Here the author would like to give some experience about the problems that he encountered during writing ***the rules*** and the practical work of the technical innovation.

2. Summarize seriously and clarify the main problems

Many small hydropower stations have accumulated plentiful valuable data on operation, inspection and repair for ten, twenty or even thirty years of operation. Unfortunately, many drawings of design and equipment are not complete and the index tags of some units are even lost. Hence, collection, analysis and summary of original data (including hydrography, engineering design, the log of operation and inspection of units and equipments), are important and should be the prerequisite for successful technical innovation.

Some problems as follows are often met during operation of small hydropower stations built earlier:

2.1 The main performance parameters don't match the practical operation parameters, the reasons are listed as followed:

1) With some objective conditions, the phenomenon of "choosing machinery for in-situ condition" or "building station for hydraulic machinery" existed in some small hydropower stations built before 1970's, which leads to the disagreement between the units parameters and practical parameters of stations.

2) Because there are few models of runner in early standard model list of hydraulic turbine runner for various range, many small hydropower stations have to use approximate models, which leads to the disagreement between the units parameters and the practical parameters of stations.

3) Some local administer rative

sectors didn't pay much attention to type-selecting design of small hydropower stations and some design institutions haven't enough serious-mind and technical level, as a result, diameter or rated head or rated speed of the turbine runner is not appropriate, which leads to the disagreement between the units parameters and the practical parameters of stations.

4) The practical hydrological data such as flow or head of some small hydropower stations is not agreeable with the design data or some necessary data is absent, which leads to the disagreement between the units parameters and the practical parameters of stations.

Each of the four cases can make turbines operate out of the optimal mode, thus results in lower efficiency, more water consumption, higher vibration and noise, more loss of output, even much shorter service life of turbines.

2.2 The performance and technology of turbine are laggard and the manufacturing quality is low.

Some runner models of the standard model list of hydraulic turbine runner promulgated in 1964, such as ZZ600, ZZ460, ZZ587, HL365, HL123, HL702, HL638 etc., are still in service now. The technical level of these runners is equivalent to that of the foreign runners made in 1930's and 1940's, whose main performance parameters is in lower level.

The turbines of these small hydropower stations have many disadvantages in manufacturing and installing quality run under defects for long time, which resulted in less capacity and reliability. The operation of turbines under low efficiency and ill-conditions is not secure and economic.

2.3 The hydraulic turbines in the rivers rich in sediment are damaged severely.

According to incomplete statistics, the phenomena of cavitation, erosion and abrasion by sediment exists in one third of small hydropower stations in China. Some turbines' guide vanes would have severe leakage just one year after major repair, and some even can't be started and stopped normally. The accident of runaway, blades cracks and break often take place so that the safety of operation cannot be assured.

2.4 The insulation of generator is aged and the pad of thrust bearing is burned out frequently.

As a result of long time operation of generators in some small hydropower stations and low insulation level of rotors and stators, some of which have already been aged severely, the accident of earth fault takes place frequently, which threatens the safety of units. Because of worse manufacturing quality and installing quality, reliability of the thrust bearing is low and accident of thrust pad burnout takes place frequently.

2.5 The hydraulic turbine and the electrical equipment don't match each other.

The small stations output of turbines is greater than the rated capacity of generators or main transformers, just like "a big horse pull a small carriage". Therefore, the design discharge of the hydropower station is limited and some abnormal phenomena such as spilling water discharge take place in operating time. On the other side, in some stations, capacity of generators is greater than output of hydraulic turbine, which just like "a little horse pull a big carriage". In such an instance, the capacity of the equipments is wasted and the operation dissipation is magnified too.

Hence, all the problems, including operational head, inflow, waste water volume, status of the electromechanical equipments, operational status of the hydraulic structures and metal structures etc., must be clarified thoroughly before the technical innovation is executed. Only if the problems have been clarified, can targeted innovation be put in practice and a successful effect be obtained.

3. Optimize the design to achieve the maximum economic benefit

In order to take an effective innovation on small hydropower stations, a technical consultation and an optimum design must be done by some qualified departments, and the redesign scheme must be checked carefully by experts. A qualified scheme can bring high level and benefits to the stations. Contrarily, inattention to the design will lead to some unwanted accidents and economic losses. For example, Hengjing Hydrpower Station (I) in Zhejiang Province whose total installed capacity is 2 3000kW is to be uprated to 2 4000kW. Chinese Bohai Company of Water Conservancy and Hydraulic Power Enginering Construction Consultancy is commissioned to take the technical consultation and select the optimum equipments (hydraulic turbine, generator, speed controller) and manufacturers. Thus not only the up to date technical productions are employed, but also the investment for unit equipment 1080 thousand yuan is saved for the owner, which reaches 15.7% of the total price of the agreement.

The four principles, that is advantage, rationality economy and particularity must be followed through the technical innovation of small hydropower station. “Advantage” is to select the turbine with optimal capability and high technical level and to select the generator and its accessory equipments with the advanced capacity and reliable security to cooperate with the turbine. “Rationality” is to deal with the inalterable restrictions of the stations well. “Economy” is to increase the annual output and improve the economic benefit with the limited investment. “Particularity” is to treat with the particular problems by the particular means. For instance, for the hydraulic turbines in the rivers rich in sediment, not only operational characteristics are to be improved but also service lives are to be prolonged by taking the comprehensive method for abrasion resistance. Only if all things are considered can the “advantage”, “rationality” and “economy” be achieved well.

At the present, the technical innovation of most small hydropower stations is the innovation on the hydraulic turbine and generator units. Generally, the following measurements are taken in the technical innovation design:

1) To the stations whose head and flow rate have slight difference with the original design value, while the equipments and the performance are laggard, the method of uprating and refurbishing can be taken. In order to improve the turbine’s efficiency and capacity, and increase the annual output, the new type of turbine that has the same or close relative height b0 of guide vane in this head range should be chosen, or the shapes and structures of the flow passage should be improved. Here is and example of Junzhuang Hydropower Station in Beijing in which six units of ZD760-LM-100 are installed. The rated discharge of each unit is 125 kW while the practical discharge is only 100kW. By employing the optimized three-blade turbine, the discharge of each unit increase to 180kW. The increment is 44% of the design discharge and 80% of the original discharge.

2) To the stations whose operating head and flow rate are less than the original design value, the method of decreasing capacity and refurbishing is effective. In order to adjust the turbine to work in the best or better conditions, and improve the operational efficiency and increase the annual capacity, the turbine’s rated head and rated output capacity should be reduced according to the practical operational head and flow of the station, and some effective turbine should be employed or the turbine should be redesigned. Here the turbine in Jiangkou Hydropower Station in Jiangxi Province whose design type is ZD587-LH-330 (H=19.5m, Q=54.7m^3/s, N=8800kW) is an example. The practical operational head is only 17m and the discharge is only 7800kW. By reemploying the turbine of ZD105-LH-330, the discharge of each unit increases and reaches 9000 kW by 15%.

3) To the stations whose operating head and flow rate are higher than the design value, the method of increasing capacity and refurbishing is effective. According to the practical operational head and flow condition, the rated head and the rated output capacity should be increased, and new turbines with high performance should be employed or the turbine should be redesigned. The rated speed of rotation should be selected accordingly, so that the turbine can work in the higher-level efficiency domain. Thus, not only the unit capacity and the operational efficiency can be improved, the annual generated energy can be increased markedly. For instance, in the Jinxi Pozhou Hydropower Station (I) in Guangxi Province whose total installed capacity is 2 500kW, the original turbine is HL300-WJ-50 (H=35m, Q=4m^3/s). However, the practical operational head reaches 40m. As a result of changing the turbine to HL240-WJ-50, the discharge of each unit increase 90kW by 18%.

In case 1) and 3), when the capacity of the turbine has been determined, the generator with accordant capacity should be employed to match it. And the accessory equipments should also be checked whether they should be changed or not.

4) To the stations in the rivers rich in sediment, the abrasion of the flow passage must be considered and the innovation method combined with the method for abrasion resistance must be taken. According to such conditions as the sediment concentration in the flow through the turbine, the medium diameter of the sediment d_{50} and the mineral component of the sediment and so on, some new types of turbine, with close or a little lower unit speed n11, slightly decreased unit flow Q11, properly reduced the model cavitation coefficient $_m$ and higher efficiency $_m$ should be employed in the innovation design. And some other meth-

ods can also be considered, such as properly increasing the relative diameter of the distribution circle, optimizing the shape of the guide vane, reducing and homogenizing the relative flow velocity in the region of the guide vane. On the other hand, in order to insure the safety operation of the turbine and prolong the service life, some comprehensive methods considering the design technology of the structures, material and the protective coating must be taken.

Other than these four cases, for stations that is "a big horse pulling a small carriage", the innovation only in the hydraulic generator may be effective, including improving the insulation level or the ventilation system to increase the capacity, and the generator, can be redesigned and made if necessary. The main transformer should be replaced if it capacity is not enough. For the station that is "a little horse pulling a big carriage", if it's impossible to increase the capacity by remodeling the turbine, just remain it to renew later.

4. Pay attention to the loss of the water conveyance system

In the reform of increasing capacity, a key component must be paid more attention to, that is water-carriage sysem of hydraulic turbine. Especially for the long penstock system, in which one diversion pipe is used by several units.

The hydraulic calculation is to account the flow and the head loss of the water conveyance system and to plot the graph of relation of head loss and flow $h=f(Q)$, so that the maximum allowable rated head and the reference flow in design can be analyzed and selected.

The regulation insurance accounting is to check the maximum increment of water pressure and rotational speed in transient process using the operational characteristics of the unit and the hydraulic characteristics of the water-conveyances system. In the mean time, the water pressure should be checked whether it is in the design range of the water-conveyances system in order to study and confirm the rationality and the possibility of the method of reinforcement.

In a word, it's the maximum flow, the head loss and the allowable maximum pressure that restrict the increment of capacity and these key factors caanot be ignored. Otherwise, the economic benefit of the technical innovation and the safety operation can not achieve. Here is an example of Dalongdong Hydropower Station in Guangdong Province whose head range is from 8m to 25m.

Originally, one Kaplan turbine imported from Germany was installed. Its type is MK141, rated head is 29m, rated flow is 12 m^3/s and the type of generator is SM14/220-32, rated capacity is 2000kW. In order to make use of the discharge in flood period to generate more energy, the station added forked pipes on the main pressure pipe in 1980 and extended two 800kW units of propeller turbines, whose type is ZD661-LH-120, rated head is 12.9m and rated flow is $8m^3/s$. Many times of experiments has been conducted in flood period after the innovation, each unit can arrive at the rated capacity under the rated head when operating singly. However, when all three units are operating at the same time with the full guide vane opening, the original 2000kW unit can only reach 1150kW, the new two units can reach only 600kW and 550kW. The total output capacity of all the three units is 2300kW that is only 300kW more than that of the original single unit. Clearly, it's the limitation of the maximum flow Q_{max} and the head loss h_{max} of the station's original water-carriage system that result in the capacity loss of the three units in flood period. This experience is worth other stations using for reference.

5. Clarify the major and minor tasks in reform for capacity increase

The hydraulic turbine and the generator are under different conditions and have different level of technological development. The turbine is the priming mover in the unit, so its operational efficiency has remarkable influence on he whole unit. Generally, the selecting-type technology of the turbine is difficult with lots of influencing factors considered, and there are many problems during the course of practical operation. Taking account of all these factors, the primary and secondary task must be clarified in reform of increasing capacity. Firstly, the innovation of turbine should be carried into execution, then the innovation of generator and electromechanical equipment as well as hydraulic metal structure of the whole station will be carried along. This is a principle that should be followed in the technical innovation of small hydropower stations.

6. Pay more attention to the environmental protection

To protect the environment is to protect ecology and the space human being exists in. And the technical innovation of small hydropower station can't make an exception. For example, in order to avoid polluting the downstream water, the oil leakage of the blades of Kaplan turbine should be restricted severely. Another example is that the noise of electromechanical equipment should be limited in the specified range.

7. Pay more attention to the final acceptance

In order to check the result of the reform of increasing capacity in small hydropower station, the performance before innovation and performance after innovation should be tested and compared for the unit whose capacity is greater than or equal to 5MW. In order to ensure the effectiveness of the technical innovation, the unit startup must be checked and only if the result is accepted, can the unit operate in test. Only if the result of test operation is accepted and the remaining problem has all been solved, can the final acceptance for the innovation works be put up, so that the long-term, high-powered and secure operation can be ensured and the investment benefit can be gained furthest.

8.Epilogue

In order to improve the level of innovation of small hydropower station, avoid some problems and gain the most economic benefit, SL 193-97 ***the rules of the technical innovation of small hydropower station*** should be carried out seriously throughout the innovation of small hydropower station. If some problems are met during the practical work, please report them to the Rural Hydropower and Electrification Development Bureau of the Ministry of Water Conservancy in time.

Reference

1. The rules of the technical innovation of small hydropower station

Chinese Hydraulic Conservation and Hydropower Press 1997.12

Long-Term Sino-Vietnamese SHP Cooperative Project Approved

The 5th Conference of Sino-Vietnamese Science and Technology Joint Committee was held on 18 March 2003 in Beijing, with the small hydro power development and SHP station automation system listed and approved by the Chinese Ministry of Science and Technology as the long-term cooperative project between China and Vietnam during the Conference. Hangzhou Regional Center (Asia-Pacific) for Small Hydro Power has been designated as the implementation organization on the Chinese side.

The cooperation as jointly approved by the two ministries of science & technology in the two countries included:

1) Study and exchange of policies and experience in SHP exploitation, development of rural economy and poverty alleviation etc.
2) Investigation and appraisal of the present SHP development in Vietnam, recommendations of appropriate development modes.
3) Development of SHP automatic controlling equipment and software appropriate for the actual situation in Vietnam, including station computer and PLC software.
4) Establishment of a pilot lab of automatic control in HPC.
5) Establishment of a pilot SHP station for high and low voltage automatic control system for wider application.

As the renewable and environmentally sound energy, playing an important role in poverty alleviation and global environmental protection, SHP development has drawn the attention from both Chinese and Vietnamese governments.

The objective of the project is to explore the mode of SHP development, SHP equipment and automatic system which are appropriate for the SHP situation in Vietnam with the aim to promoting the SHP development in Vietnam. The duration of the cooperation is three years (from May 2003 to May 2005).

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

Ecuadoran Guests Visited HRC

On 21 March, a group of Ecuadoran guests headed by Mr.L.Honding paid a visit to HRC, as introduced by Beijing Guo Jing Import & Export Co., Ltd. HRC's honorary director, Mr.Zhu Xiaozhang, deputy secretary general of HRC Secretariat, Mr.Pan Daqing received the guests.

Ecuadoran Guests heard in Brasil early that the real country rich in SHP technology and experience is China, however for a quite period of time they were unable to contact with the appropriate the SHP organization in China. After the brief introduction of both sides, the Ecuadoran guests felt that HRC was the right one to cooperate for the development of SHP resources in Ecuador. In regard with the exploitation procedures, generation cost, electricity price, designing expenditures, and training etc the Ecuadoran guests made a detailed inquiry and evaluated highly HRC's expertise in SHP training, planning, design, automation and equipment supply, expressing the keen expectation of long-term SHP cooperation with HRC so as develop the SHP potential in Ecuador and in other Latin American countries jointly. Currently, there are a couple of SHP sites waiting for exploitation in Ecuador. After coming back, the Ecuadoran side may send invitation to HRC for SHP technical assistance. Both sides agreed to keep close contact for further exploring the modes of concrete SHP cooperation. ¡ö

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

Australian Mr.Polglase Visited HRC

Mr.Polglase from Hydro Tasmania of Australia paid a visit to HRC on 15 April. Hydro Tasmania of Australia is a company specialized in hydro power international consultation with its headquarters in Australia. It is powerful in SHP exploitation, construction and finance etc. It is also one of the organizers for the "Water & Energy" session of the Third Water Forum recently held in Japan. At the Forum Mr.Polglase got acquainted with HRC and this time he paid a special visit to HRC after attending a meeting in Beijing.

Both sides conducted friendly and detailed talk on the containerized mini hydro technology and identified the work in the next phase. Also, the utilization of the latest renewable energy like wind power and battery technology were discussed. Meanwhile, information on the SHP investment both home and abroad was exchanged. The prospect for the bilateral cooperation was felt promising. ¡ö

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

Ms. Cheng Xialei, Deputy Director of HRC, as one of the 52 experts of the Chinese delegation, is participating in the Third World Water Forum, which was opened in Kyoto, Japan on March 16.

The experts' delegation of China, headed by Prof. Zhang Ruikai, president of NHRI, has submitted 22 papers to the conference. 17 experts will deliver a speech at the conference and 5 experts will make an address on the Asian-Pacific Day.

The delegation will share the abundant experience and new ideologies on water resource development with the peers all over the world. Fruitful results are much expected to be scored. ¡ö

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

Improving the cost-effectiveness of small hydro through intelligent load management

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Introduction

In recent years a considerable amount of effort has been spent on reducing the capital costs of stand-alone hydro schemes. Savings have been made in a number of areas, including standardisation of scheme components, replacement of mechanical and hydraulic controls with power electronic based systems, and labour contributions from project beneficiaries. However, little attention has been given to improving load factors in order to maximise the benefits from schemes.

Stand-alone hydro schemes are often characterised by high peak and low average demand. This is particularly the case with community electrification schemes in developing countries where average demand can be as low as 15 to 20% of the peak demand[1]. This has two main disadvantages:

1) Generators are invariably overloaded at peak times. This results in undervoltage operation for small overloads and repeated tripping for large overloads. The result is customer dissatisfaction and productivity losses where there are income-generating activities.
2) During times of low demand, the power from the hydro is only partially utilised and, since most stand-alone schemes are run-of-river, available energy is wasted. This reduces the benefits to the recipients and the overall cost-effectiveness of the scheme.

This paper introduces two technologies for demand-side management that together tackle the problems of overloading and low load factors. Their application to overcome load management problems at a rural hospital in Uganda is described.

THE TECHNOLOGIES

Peak demand control by means of current limiters

The use of kilowatt-hour meters is so widespread that it is usually assumed that direct measurement of electricity consumption is the only acceptable basis for charging for an electricity supply. However, kilowatt-hour meters do not limit peak demand, and as a result there are many stand-alone electrification projects where demand has risen and exceeded the supply capacity with serious consequence to supply quality and reliability.

With a current limited supply, the consumer is allowed to draw a current up to a prescribed limit at all times, and pays a fixed monthly service fee according to the rating of the current limiter. If they exceed the current limit they are temporarily disconnected. By fitting current limiters to all connections the maximum demand can be controlled to within the capacity of the generator. Demand growth can be managed by only allowing upgrading to higher rated current limiters in the event that there is surplus capacity.

The concept of a fixed or limited current connection is well established, although until now it has suffered from a lack of suitable technology. In Zimbabwe standard miniature circuit breakers are used as current limiters, replacing metered supplies to more than 100,000 households connected to the main grid[2]. However, these circuit breakers have a serious drawback – as they have to be readily accessible for resetting, they can be bypassed easily by fraudulent consumers.

A purpose designed current limiter, called PowerProvider has recently been introduced which auto-resets after a fixed time delay. These are more convenient to the user as, in the event of a trip, they can just reduce their load and wait for the power to come back on. In addition, they are more secure against tampering and bypassing as they can be mounted on a service or distribution pole outside the house.

The fixed monthly payments for a PowerProvider supply make budgeting easier for the consumer and reduce the likelihood of defaults on payments. An annual advance payment option can be offered to enable farmers to pay for their supply when income is generated at harvest time[3].

Improved off peak energy utilisation through distributed load controllers

Most small hydro schemes below 250kW capacity use an electronic load controller to regulate the generated frequency by dissipating any surplus power in a resistive load known as the ballast or 'dump load'. For schemes of this size, such controllers are cheaper and more reliable than flow control governors. The energy dissipated in the ballast is rarely used productively. There are a number of reasons for this:

- The ballast heaters are usually installed in the turbine house for cooling by running water and this is often remote from the consumers.
- The uncertain and variable power dissipation is unsuitable or inconvenient for many applications.
- The ballast is essential for correct operation of the hydro system and therefore it should not be used for any application that may compromise its reliability.

The Distributed Intelligent Load Controller (DILC) allows productive use to be made of the surplus power available without overloading the system[4]. A number of DILCs are fitted at convenient points on the distribution system, each controlling a low priority load. Typical loads are water heaters or room heaters. The DILCs sense the generated frequency and switch on their loads when the frequency is normal. Overloading will cause the frequency to fall and the DILCs sense this and switch out the loads that they control. The DILCs can be set at different frequency thresholds so that the low priority loads can be prioritised. The use of DILCs enables more productive use of the generated power, reducing the amount of energy that is dissipated in the ballast. The following case study shows how, by using both DILCs and PowerProviders, problems with overloading can be solved and more productive use of energy can be achieved.

THE CASE STUDY-KISIIZI HOSPITAL,UGANDA

Background

Kisiizi hospital was founded in 1958 and is situated in South West Uganda. It serves a large rural area. In the mid 1980's a 60kW hydro system was installed using a turgo turbine, synchronous generator and electronic load controller. This replaced a smaller hydro system and is the only electrical power supply for the hospital.

As well as supplying power to the hospital, the generator supplies the residential accommodation for the management, doctors, nurses and ancillary staff. From the outset the power was supplied free of charge and seen as beneficial for attracting quality staff. Over the years the hospital and staff numbers have grown and by the early nineties the load was exceeding the power generated at peak times. The consequence of this was that the overload protection system would shut down the turbine and the entire hospital complex would be without power. Sometimes the shutdown would occur during an operation, putting the life of the patient at risk.

A number of attempts have been made to control the peak demand. These have included installing time switches on water heaters so that they operate only at night and confiscating electric cookers and other high power loads from residences. However, improvements have always been temporary as demand in the hospital has continued to grow and some staff have failed to obey the restrictions on appliance usage.

By 2001 the extent of the overloading problem was such that it frequently proved very difficult to sufficiently reduce the load after a trip to a level where an immediate repeat trip would not occur. As a result, an isolation switch was fitted so that the entire residential supply could be disconnected if necessary. This was a drastic measure in view of the effect on the staff and their families.

Load management package

After discussions with management and staff at the hospital, a new load management package was designed to provide the following:

1. A secure supply to the hospital.
2. Limited secure supplies to the staff houses for essential loads, such as lights and refrigerators.
3. Additional power to the staff houses at off-peak times, such that water heaters and other high power appliances can be used when sufficient power is available.

The limited secure supplies were made using 83 PowerProvider type current limiters, which were fitted one per house. The current ratings are 1 Amp, 2.5 Amps and 5 Amps, which correspond to 230VA, 575VA and 1150VA. The current rating fitted was determined according to the seniority and needs of the particular staff member. If a household trys to exceed the current rating of their PowerProvider supply only they are inconvenienced by temporary disconnection and the supply to the hospital and other residences is safeguarded.

DILCs are used to provide extra power to the staff houses at off-peak times. 40 DILCs were fitted in senior staff houses and communal buildings such as the nurses' hostels. A dedicated electrical circuit, separate from the circuits limited by the PowerProvider, is supplied for the DILC and provided a bonus supply of up to 13 Amps.

Some DILCs were designed to replace the time switches on the water heaters and the others were fitted with a standard socket so that other high power appliances such as cookers, irons and kettles could be used. The trip frequencies were set at between 47 and 49 Hertz for the water heater DILCs and between 46 and 47 Hertz for the other DILCs. As a result, at the rated frequency of 50 Hertz all the DILCs are switched in. When the hospital load is increased so that the generator output is exceeded, the frequency falls and causes some or all of the water heater DILCs to switch off. At higher hospital loads, some or all of the other DILCs are switched off. Hence, the supply to the hospital is secured and the high power domestic appliances have a higher priority over the water heaters.

The PowerProviders and DILCs were fitted between September and December 2002. Generator performance data, prior to and after fitting of the units, was obtained by a computer based monitoring system that was installed in March 2002.

Results to date

Figure 1 shows the number of system trips before March 2002 and December 2002. There is a clear reduction in the number of trips, which indicates that the load management package is producing a marked ben-

Figure 1: Occurrences of Whole Electricity System Trips

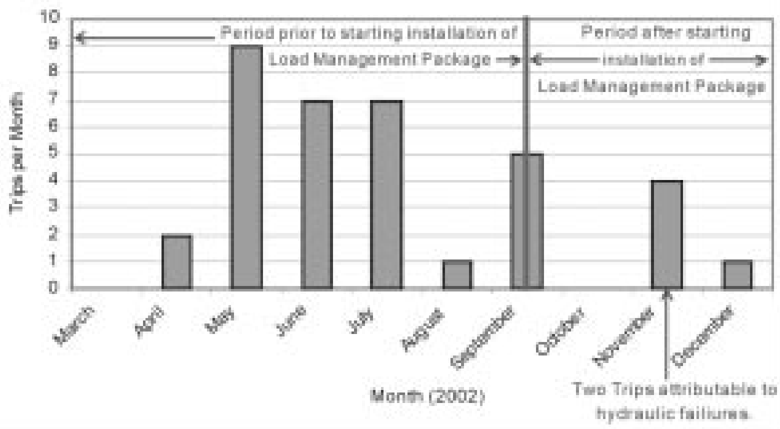


Figure 2: kW Hours Energy Consumed 12 July 2002

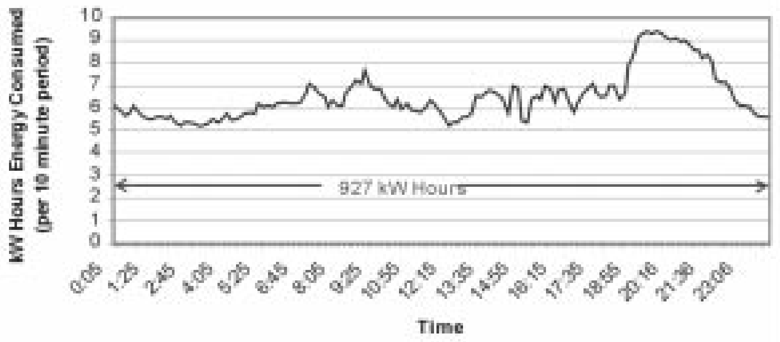
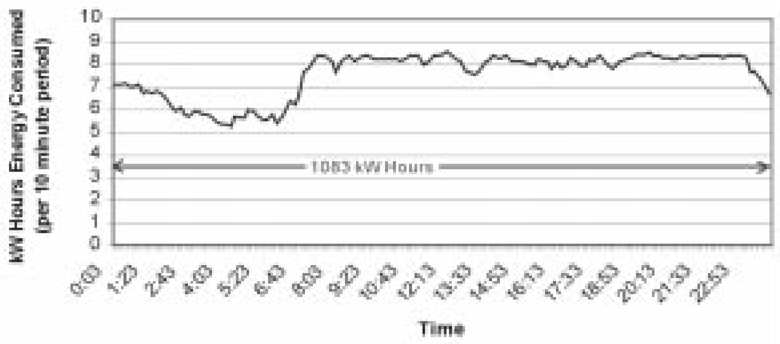


Figure 3: kW Hours Energy Consumed 13 December 2002



efit. Some system trips are due to trashrack blockages or problems with the turbine-generator and not a result of overload and therefore it is possible that none of the trips in November or December were due to overload.

As well as the improvement in terms of fewer system trips there has been a noticeable increase in the amount of power consumed in the hospital and residences and hence a reduction in power dissipated in the ballast. Figures 2 and 3 show results for a typical day prior to installation of the load management package and at the end of the installation period. With all the DILCs and PowerProviders installed there is an increase of more than 15% in the power consumed in the hospital and residences and little or no power is dissipated in the ballast between 7.30am and 11.30pm.

Customer satisfaction

There was an initial period of disquiet as people went through a learning process and established a practice of switching off loads when they were not required so as to free up their PowerProvider controlled supply. Households that did not have a 5 Amp PowerProvider or access to a DILC socket complained that they were unable to iron with their electricity supply. This is being overcome by providing more DILCs in communal areas and offering to modify the power consumption of existing irons so that they can be used with 2.5 Amp PowerProviders.

Overall the feedback has been positive, with praise for the improved reliability of the supply both in the hospital and homes. Also there has been a significant increase in the amount of hot water available and people are pleased once more to be able to use cookers, kettles and other previously banned appliances.

Conclusion

DILCs and PowerProviders are complementary technologies, which are now proven to improve the reliability and productive use of power from small hydro schemes. They can be used to overcome problems with overloading and poor energy utilisation on existing schemes, provided that there is strong management. However, they are best installed at the beginning of hydro projects so that good practice is introduced from the outset.

Acknowledgements

We would like to thank Dr Bill Cave and the management and staff at Kisiizi hospital for their assistance with the project and to acknowledge the financial support of the UK Department of Trade and Industry.

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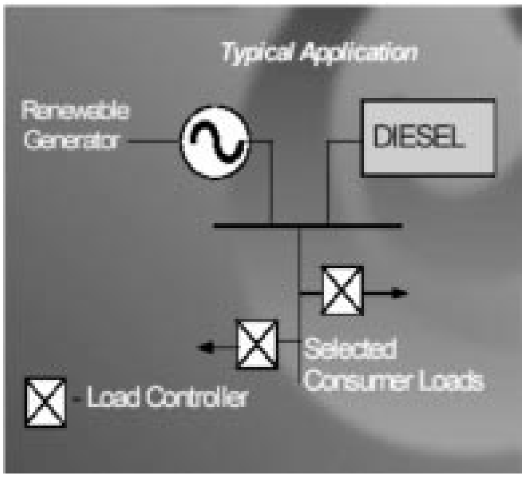
Distributed intelligent Load Controllers

Technical Specification

A range of low-cost microcontroller based devices designed to improve the reliability and efficiency of isolated power systems.

This is achieved by controlling or matching loads connected to the generator and the power, which is available.

It is possible to provide both centralized and distributed solutions.Used together, the controllers will provide a total system solution.



Features/benefits	Governing Load Controller	Automatic Load Controller	Current Sensing Load Controlller
Disconnect non-essential loads at peak demand, (e.g., space & water heating)			
Disconnect loads according to consumption			
Temporarily disconnect non-vital loads during overload conditions			
Protect sensitive loads from “brown out” conditions			
Increase system efficiency and reduce power losses			
Increase Renewable Energy penetration			
Gradual re-introduction of loads as power system stabilizes			
Provide system soft start			
Facilitate stable operation with 100% wind penetration			
Provide governing action by matching loads to the available power			
Use excess energy in a distributed and useful way			
Provide a fault tolerant solution			

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	Governing Load Controller	Automatic Load Controller	Current Sensing Load Controller
Power Supply	50Hz model- voltage 180V to 260V a.c frequency 45 to 55 Hz 60Hz model- voltage 85V to 130V a.c frequency 55 to 65 Hz Current consumption appro×75mA	50Hz model- voltage 180V to 260V a.c frequency 44 to 50 Hz 60Hz model- voltage 85V to 130V a.c frequency 53 to 60 Hz Current consumption appro×75mA	Voltage 180V to 260V a.c Frequency 45 to 55 Hz Electrical consumption 30mA
Frequency Measurement:	Zero crossing techniques 0.1% accuracy, defined in firmware	16 frequency thresholds defined in firmware	0.1% accuracy
Voltage Measurement:	N/A	3 voltage thresholds defined in firmware	N/A
Current Measurement:	N/A	N/A	0 to 50A
Load Switching:	Opto-coupled TRIAC	N/A	N/A
Tuning:	self tuning membersip functions	N/A	N/A
Configuration Options:	N/A	50/60Hz operation Time delay-random values in 4 ranges from 8 seconds to 16 minutes Frequency threshold. Voltage threshold (voltage detection can be disabled)	N/A
Display:	Green led-indicating load status Amber led-indicating self tuning	Green led-Indicating load status Amber led-Indicating delay progress	Green led-Indicating supply connected Amber led-Indicating supply overloaded Red led-Indicating supply disconnected
Switching Capability:	Standard-3kW load single phase Optional-greater than 3kW load (single or 3 phase)	Standard-3kW load single phase Optional-greater than 3kW load (single or 3 phase)	7500 VA
Enclosure Options: (Can be customized)	DIN rail mounted (100mm wide×75 high× 110deep) Wall mounted (180mm wide×180 high × 90 deep)	Plug mounted-(70mm wide×110 hign×deep) Din rail mounted-(50mm wide×75 high×110 deep) Wall mounted-(170mm wide×110 high×65 deep)	Wall mounted-(170mm wide×110 high×65 deep)
Weigh:	DIN rail mounted-500g wall mounted-750g	Plug mounted-260g DW rail mounted-200g Wall mounted-390g	3kg
Standards:	Low Voltage Directive (72/23/EEC) EMC Directive-(89/336/EEC) CE Marked	Low Voltage Directive (72/23/EEC) EMC Directive-(89/336/EEC) CE Marked	Low Voltage Directive (72/23/EEC) EMC Directive-(89/336/EEC) CE Marked
Environmental:	Operating Temperature Range-40 to +85 degrees C	Operating Temperature Range-40 to +85 degrees C	Operating Temperature Range-40 to +85 degrees C Enclosure rated at IP 54

The Editor' s Note

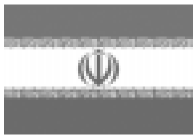
Beginning from this issue, we will successively publish relevant articles from the "Third World Water Forum" held on March 16-23,2003 in Japan. The Forum revealed that around the world, numerous water issues have arisen, including water shortages, water pollution and increased damage by flood and draught among others. Moreover, the areas suffering from water based problems including food shortages and epidemics have been expanding, while in other areas, water related problems have led to international conflicts. If adequate actions are not taken to alleviate the present conditions, it is expected what water issues will be much wore serious in the near future.

During the forum, the "First International Summit on Sustainable Use of Water for Energy" was held, in Kyoto which reviewed the relationships between water and energy, with a focus on hydropower and was organized to follow-up the recommendations of the "World Summit on Sustainable Development (WSSD, in Johannesburg, South Africa, 2002).

Attended by Ministers and Heads of Delegation from more than 170 countries, the Kyoto Ministerial Conference formed the conclusion of the Forum, which culminated in the ratification of a formal Declaration. Some specific reference to hydropower was included in the Declaration, such as (Item 15) "We recognize the role of hydropower as one of the renewable and clean energy sources, and that its potential should be realized in an environmental sustainable and social equitable manner." Both the Kyoto Declaration and the Johannesburg Implementation plan are seen as essential mandates for the future role of hydropower, the contents of which include: 'Renewable policy/legislation should include hydropower of all scales; according to the circumstances, there is a role for both large and small schemes.' etc.

The International Hydropower Association (IHA) presented these documents at the Kyoto summit, one of which is a volume of Country Reports, reviewing the past, present and future roles of water for energy in 16 countries (representing a cross-section of countries at different stages of development). The other two documents include a comprehensive review of the Role of Hydropower in sustainable development and a draft of sustainable Guidelines, etc. These documents will surely bring about crucial momentum to the small hydropower sectors. We therefore would like to select a series of articles from the above stated documents to publish in our journal for offering to our readers.

IRAN



Report submitted by:
Deputy Minister for Water Affairs, Ministry of Energy

1.INTRODUCTION

1.1 Location and physical description

Iran is in the south of Asia, between 44º02´ and 63º20´ E longitude and 25º03´ to 39º46´ N latitude. The country covers an area of about 1.65 million km^2. Having a perimeter of 8731 km, Iran is bordered to the north by Armenia, Azerbaijan, the Caspian Sea and Turkmenistan; to the east by Afghanistan and Pakistan; on the south by the Oman Sea, the Strait of Hormuz and the Persian Gulf; and, to the west by Iraq and Turkey. A geographical and topographical map of the country is shown in Fig. 1.1.

Iran is a mountainous country, with mountains covering more than 57% of its territory. The Zagros mountain range, with a length of about 1300 km and an average width of 200 km, consists of a range of parallel highlands. There are numerous plains and valleys between the highlands, through which several permanent and seasonal rivers flow. The Alborz mountain range, with a length of 1500 km, extends from Azerbaijan to Khorassan Province. It is 120 km in its widest part to the north of Tehran.

Taking into account the Alborz and Zagros mountain ranges and the central plateau, and also from topographical point of view, Iran can be divided into the following main regions:

- Mountainous terrain, which consists of the lands covered by the country's two main ranges and some other mountains located in the central plateau of the country.
- The central plateau, which is surrounded by the mountains and

contains vast deserts (Dasht-e-Kavir and Kavir-e-Lut), alluvial plains, closed basins, lakes and Salinas.

- Khuzestan plain, which is an extension of the Bein-ol-Nahrein plain of Iraq, as well as some littoral plains along the coasts of the Persian Gulf and the Oman Sea in the south of the country.
- The coasts of the Caspian Sea.

1.2 Population, settlement and trends

The population of the country was estimated at 65,865,362 in 2002. There are higher concentrations of people in the north and west. Tehran is the capital, and the largest city. Other major cities include Mashhad, Tabriz, Esfahan, and Shiraz. The central parts of the country, which are covered by deserts, including salt deserts, are virtually uninhabited. Since 1881, the country's population has increased from 7.7 to 65 million. In other words, the annual population growth rate has increased from 0.6% to 3.9% within the last 120 years.

With a population of 65 million, and a GDP of US$115 billion, Iran is the second most populous country and has the second largest economy in the region. It is also the second largest OPEC producer, and has the world's second largest gas reserves. Key economic parameters and functions are as shown in Tables 1.1 to 1.3.

Table 1.1 – Some Economic Parameters in Iran

Economic parameter	Year			
	1981	1991	2000	2001
GDP (US$ billions)	100.1	91.5	101.5	114.1
Gross domestic savings/GDP	18.8	25.1	38.7	35.8
Current account balance/GDP	-3.4	-11.2	13.3	4.2
Interest payments/GDP	0.2	0.0	0.3	0.2

Table 1.2 – Structure of the Economy

Economic Parameter (% of GDP)	Year			
	1981	1991	2000	2001
Agriculture	21.5	23.1	17.7	18.6
Industry	31.4	28.3	33.3	30.1
Manufacturing	10.0	14.0	15.3	12.5
Services	34.5	48.7	49.0	51.3

Table 1.3 – Trends in trade (US$ millions)

Economic parameter (average annual growth)	Year			
	1981	1991	2000	2001
Total exports (FOB)	11,831	18,661	29,900	26,000
Fuel	11,491	16,012	24,280	19,339
Total imports (CIF)	13,138	25,190	17,900	21,600
Fuel and energy	1,000	400	274	625
Export price index (1995=100)	1,000	400	69	70
Import price index (1995=100)	51	93	58	58

2. WATER TRENDS

2.1 Trends and issues in the use of water

2.1.1 Water uses

Table 2.1 shows various water consumers from 1963 to 2001 in comparison with the population growth and hydropower. Although consumption in the agriculture sector is much more dominant in comparison with the two others (industrial, urban and rural), it has had much less growth.

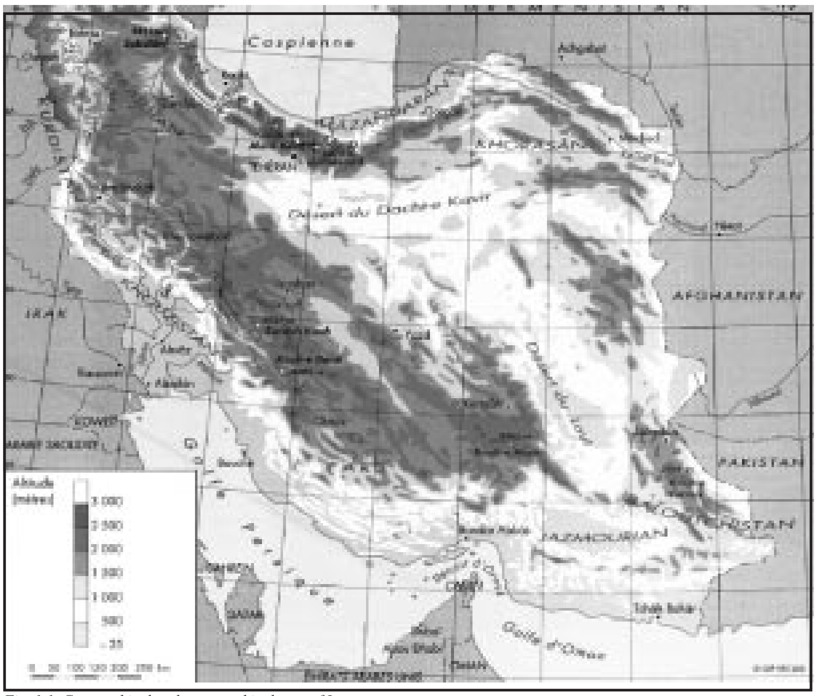


Fig. 1.1. Geographical and topographical map of Iran

2.1.2 Water quality

Among the most important factors impacting on the environment and the quality of water resources in the country, wastewaters, waste and recycled water could be mentioned. The total renewable water resources of the country are 130 billion m^3 per year.

2.1.3 Water supply

Concerning the total number of 70 dams under construction and about 200 under study/design, Iran is among the leading countries in the world.

The water supply services available at present are as follows:

- 95 storage dams with a regulating capacity of 32 billion m^3;
- primary drainage networks covering more than 1.4 million ha;

- secondary drainage networks covering 0.6 million ha;
- hydropower plants with an installed capacity of 2051.5 MW and energy production of 6516.6 GWh/year; and,
- 110 000 deep wells and 300 000 semi-deep wells with a total capacity of 44 billion m^3.

2.1.4 Legislation

The major laws implemented with regard to water affairs in the country cover the following aspects;

- the preservation and maintenance of groundwater resources (1966);
- water and its nationalization (1968);
- fair distribution of water (1982);
- maintenance and fixing of boundary river beds (1983); and,
- the encouragement of investment in water projects (2002).

2.1.5 Water security and meteorological changes

Generally, the changes in climate will affect the existing hydrological cycle. Changes in the cycle are likely to have a significant impact on water resources. There could be considerable change in river flows, especially in arid and semiarid regions thus, increasing the risks in planning new projects (for instance, hydro projects).

An analysis of more than 30 years' data collected from various meteorological and hydrometrical stations in Iran indicates that, of 143 meteorological stations, 136 show undesirable climatic changes, having a tendency towards an arid climate; and out of 992 hydrometric stations, 36 show a decrease in normal discharge and an increase in the number of observed floods, which is the indicator of arid regions.

In recent years, an increase in the Caspian Sea level has inundated coastal areas. In the past 30 years, the temperature in Iran has increased by about 0.5°C on average, and a change in the time of snowmelt and a decrease in precipitation have been observed. Also, an increase in the frequency of destructive floods and droughts has been recorded in hydro-meteorological data.

Research on the effects of global warming on hydrology and water resources conditions in Iran has been carried out on several rivers and lake basins by using historical hydro-meteorological data and runoff models, together with global warming scenarios. The research projects have been carried out with no restriction of areas. Also, comprehensive assessment work on the impact of global warming has been conducted. The main results obtained so far are:

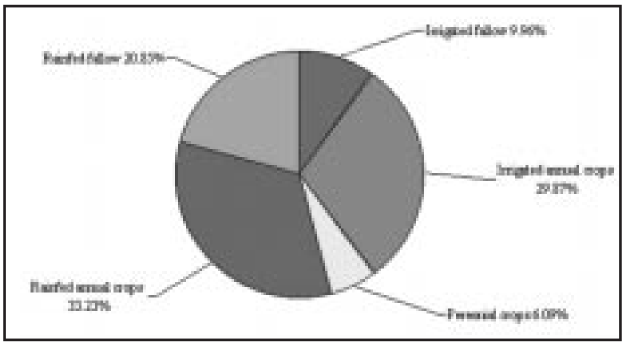


Fig. 2.1. Irrigated and Non-irrigated land use.

- Based on different climate change scenarios, as the temperature rises, evapotranspiration will increase in most river basins throughout the year. A 2°C to 6°C increase in temperature will augment the annual evapotranspiration by 6% to 12% in the 30 basins throughout the country and decrease the annual runoff within the range of 1% to 5%.
- The modelled runoff distribution shows a significant increase in peak flood flows during the winter, and a decrease in mean river discharge.
- Global warming will reduce the snowfall in winter with a significant change in the seasonal pattern of river flows (a decrease in the snowmelt-generated spring flow). This change affects various water uses and the operation of existing water resources management facilities.

2.2 Relationships between water and energy

2.2.1 Agriculture

Of the total area of 1.648 million km^2, 15,458,900 ha are used for cultivation. The principal agricultural products are wheat, rice, other grains, sugarbeet, fruits, nuts, cotton, dairy products and wool. According to the data for the year 2001, cultivated lands have used 86 billion m^3 of the water resources of the country (92.4% of the total water resources). With regard to the climatic condition, it is not

Table 2.1 – Water consumption changes (1963-2001)

Sector	Year					Average annual
	1963	1979	1988	1996	2001	growth (%)
Agriculture (billion m^3)	44.1	49.8	70.6	81.4	86	1.77
Urban and Rural (bcm)	0.57	1.9	3.2	4.5	6	6.39
Industrial (bcm)	0.03	0.4	0.7	0.9	1.1	9.94
Total (bcm)	44.7	52.1	74.5	86.8	93.1	1.95
Hydropower generated (GWh)	211	6249	7310	7377	502	6 8.7
Population (millions)	23.4	36.4	53.4	60	65	2.72
Per capita, urban and rural consumption (m^3/y)	25.6	52.2	59.9	75	92.3	3.43
Per capita total consumption (m^3/y)	1910	1431	1395	1447	1432	-0.75

Table 3.1 – Production of primary energy and share by fuel type, between 1987 and 2000 (Mboe)*

Type of fuel	Amount				Share (%)				Annual growth rate(%)
	1987	1993	1999	2000	1987	1993	1999	2000	
Crude Oil	891.7	1426.7	1234.1	1373.0	90.8	86.2	76.8	77.6	3.4
Natural Gas	69.6	206.7	356.7	381.3	7.1	12.5	22.2	21.5	14.0
Solid Fuels	4.8	3.6	5.7	6.0	0.5	0.2	0.4	0.3	1.7
Hydro Energy	13.1	15.3	7.8	5.7	1.3	0.9	0.5	0.3	-6.2
Renewable Energy	–	–	0.1	0.05	–	–	0.004	0.003	–
Non-Commercial Fuels	3.3	3.1	2.8	2.7	0.3	0.2	0.2	0.2	-1.5
Total	982.5	1655.5	1607.2	1769.8	100.0	100.0	100.0	100.0	4.6

*Mboe = Million barrels of oil equivalent

possible to apply rain-fed fallow for most of the country. For this reason, a considerable part of the available water is used for irrigation purposes. 4.6% of the total produced energy is consumed in the agriculture sector.

2.2.2 Resource development

The total annual fuel production was 1700 million barrels in 2001 of which about 1400 million barrels is that of crude oil.

The number of active mines has increased from 718 in 1986 to 2436 in 1998. The total quantity of minerals produced has increased from 48,710 kt (1 kt = 1000 tons) in 1991 to 75,751 kt in 1999.

2.2.3 Industry

About 30% of the GNP comes from industries in the country. In 2001, 1.1 billion m^3 of the available water resources were used by industry.

2.2.4 Power generation sources

According to statistics for electricity generation from 2001, the total actual capacity of powerplants under the management of the Ministry of Energy was 28,032 MW. The breakdown was as follows: steam powered plants, 14,402 MW (51.4%); combined cycle, 4060 MW (14.5%); gas, 7038 MW (25.1%); hydropower, 1999 MW (7.1%);diesel, 533 MW (1.9%).

3.ENERGYTRENDS

3.1 Energy sector

The macroeconomic sector provides inputs to the energy sector and is also a receiver of inputs from the energy sector.

Oil has been the main domestic fuel since 1960, and has played a major role as the principal generator of export income and surplus finance. In the past, annual crude oil production in Iran fluctuated considerably, reaching a peak of 6 Mb/d (million barrels/day) in 1974, decreasing to 1.3 Mb/d in 1981 and then increasing under the Second Five-Year Plan to 3.1 Mb/d and in 2001 to 3.5 Mb/d. The annual level of oil production is now no longer determined by production constraints, but is regulated by OPEC's production quota. This means that the exportable surplus of oil is determined (at least in the short term) by the domestic level of demand. The reduction in oil consumption by energy savings and fuel substitution has therefore become the most important policy objective in the national energy policy.

In view of this background and the country's vast reserves, natural gas is destined to become the fuel of the future, replacing other fuel wherever it is economic. Natural gas production started in 1966 for exports to the Former Soviet Union. During the 1970s, its use in Iran began to develop as well. Today, it has become a major fuel in Iran. The annual production of natural gas is about 72 billion m^3, of which more than one-third is used for power production and the rest in the residential and industrial sectors.

Iran's primary resource base includes oil, natural gas, hydropower, coal and solar energy. The sources of primary energy production are given in Table 3.1 Geothermal energy is about to be developed on an accountable scale. The present estimates of recognized reserves are equivalent to 99 billion barrels of oil (about 9.4% of the world total) and 26.6 trillion m^3 of natural gas (close to 16.8% of the world total and second largest national reserves in the world). The present estimates indicate that the recognized reserves of coal are about 13 billion tons (see Table 3.2, in Mboe).

The final demand structure of energy is characterized by a decrease in the oil and a considerable increase in the natural gas shares during the

Table 3.2 – Recognized fuel reserves in Iran

Type of fuel	Recognized reserve (1000 Mboe)	Share 1993	Annual production (1000 Mboe)	Reserve/Prod ratio
Oil	99	30%	1.3	76
Natural Gas	168	51%	0.4	420
Coal	62	19%	–	–
Total	329	100%	1.7	–

*Mboe = Million barrels of oil equivalent

Table 3.3 – Power sector in Iran

Power sector parameter	1989	1998	1999	2001	Annual growth rate 1989-91 (%)
Installed capacity (MW)	14442	24437	25205	28032	5.7
Generation (GWh)	48725	97862	107207	12427	8.1
Transmission and distribution losses (%)	14.7	15.5	15.7	17.3	
Consumption (GWh)	39956	77646	84656	97171	--7.7
-Residential (%)	39.5	36.9	35.2	33.8	
-Industry (%)	21.2	31.1	31.3	34.6	
-Others (%)	39.3	32.0	33.5	34.6	
Number of consumers (1000)	9338	14128	14875	16345	4.8
Number of Employees	60740	52158	51943	51262	-1.4

Table 3.4 – Installed capacity of powerplants

Type	1988		1999		2001		Av. annual growth rate (%)
	MW	%	MW	%	MW	%	
Steam	7475	54.6	13102	52.0	14402	51.4	5.2
Combined cycle	–	–	3546	14.1	4060	14.5	–
Gas	3489	25.5	5984	23.7	7038	25.1	5.5
Hydro	1914	14	1999	7.9	1999	7.1	0.3
Diesel	803	5.9	574	2.3	533	1.9	-3.1
Total	13681	100	25205	100	28032	100	5.7

last ten years. The share of oil products in the final consumption of energy has declined from 79.8 to 62.7% while the natural gas share has increased from 7.1 to 28.3%.

The residential/commercial sector has been the most important energy-consuming subsector during the period 1988-1999, accounting for more than one-third of the total consumption. Energy demand for transport amounted to more than one quarter of the total.

Iran is one of the few oil producing and exporting countries in the world to carry out programmes for improving energy efficiency of the various consuming sectors. The conventional and easy way to improve energy efficiency is to adjust the prices of energy products to cover production and delivery costs; moreover, a high tax on energy products is frequently applied in many countries. As a result of its low prices, population and economic growth, the energy intensity in Iran has been constantly increasing during the last few years.

One of the main environmental problems that Iran is currently facing is air pollution, especially in Tehran. The energy-related carbon emissions throughout the country have increased steadily, corresponding very closely to energy consumption. Efforts have been made in recent years to reduce carbon emissions through the use of gas in powerplants.

3.2 Electricity generation

Some of the main data for the power sector are shown in Table 3.3, and the capacity contributed by the various types of plant is shown in Table 3.4. The annual average growth rate of installed capacity, generation, consumption and the number of customers were 5.7, 8.1, 7.7 and 4.8% per annum during the period 1989-2001.

In 2001 Iran's powerplants, including those under the management of Ministry of Energy and heavy industries, generated about 127 TWh of energy.

3.3 Export/import of energy

Iran is a resource-rich country, with the fifth largest oil reserves in the world (about 90 billion barrels) and the second largest gas reserves (about 23 trillion m^3). The amount of crude oil and natural gas production in Iran is shown in Figs 3.2 and 3.3.

The revenue for fuel and energy exports increased from US$ 11,491 million in 1981 to US$19,339 in 2001. The cost of fuel and energy imports decreased from US$1000 to US$625 for the same period.

Since the mid-1990s, attempts have been made to inject substantial amounts of foreign capital into Iran, in the hope of facilitating oil and gas development. For example, in 1995 and 1998, Iran encouraged international bids based on "buy-back contracts" (a type of contract which promises investors cost recovery and certain returns on investment).

The following factors necessitate the injection of foreign capital:

- It is a matter of great importance to secure and boost earnings from the oil and gas sector, the largest single revenue source.
- Restoring the economy for the Government is one of the top priorities.
- In addition to new oil and gas development, Iran has to keep oil flowing from ageing oilfields currently in operation. This involves

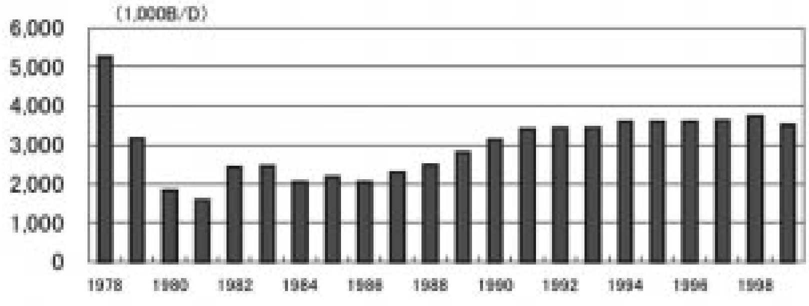


Fig. 3.2. Crude oil production in Iran (1978-1998).

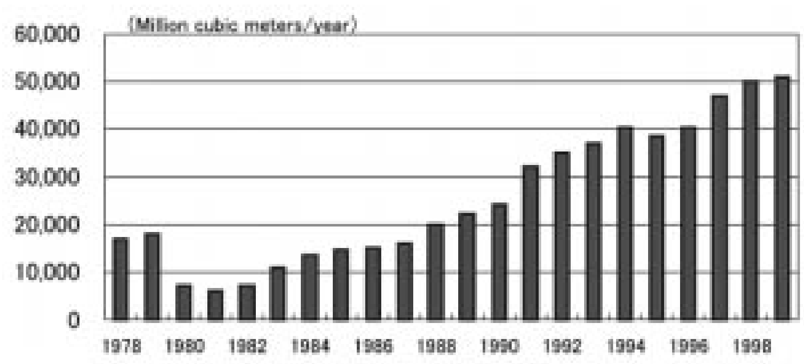


Fig. 3.3. Natural Gas Production in Iran (1978-1998).

huge investments, beyond the capability of the country to raise domestically.

- The development of new fields and the production maintenance at existing oilfields both require the introduction of advanced technologies and management skills held by international oil and gas companies, to cut production costs and improve management efficiency.

However, with the aim of securing better investment opportunities in the future, international oil companies (most notably the major ones) are showing positive interest in the terms currently available. Because American firms are not allowed to invest directly in Iran (because of US economic sanctions), European companies such as Total Fina Elf (France), ENI (Italy) and RD/Shell (UK/Netherlands) are acting as major investors. Also noteworthy is that recent moves to open upstream sectors in neighbouring countries such as Saudi Arabia and Kuwait are encouraging the Iranians to consider more flexible terms for future contract negotiations.

3.4 Renewable energy development programme

Results of studies show that Iran has a huge potential for renewable energy, especially in the solar sector. There is great potential for the large-scale application of solar energy systems. By the utilization of solar energy developed over an area of 15,510 km^2, (less than 1% of Iran's land), the country could produce enough hydrogen to supply its present annual energy demand and export 6.77 EJ of clean energy. Renewable energy development goals for the present plan period are shown in Table 3.5.

3.5 Present development plan (2000-2004) for the energy sector

3.5.1 Challenges

Reviewing the previous development plans (the First and Second Five-Year Plans), some of those demonstrating the policy of sustainable energy development are as follows:

- fair sales prices for energy carriers (with respect to the costs);
- an appropriate consumption pattern to avoid high per capita consumption of petroleum products, and high and growing energy intensity, compared with countries with similar energy-economics structures;
- importation of appropriate consuming technologies and equipments;
- governmental entities and affiliated industries within the sector; and,
- a protective policy regarding renewable energy production, and incentives for private sector investment in this field.

3.5.2 Energy sector objectives

These can be summarized as follows:

- sustainable economical supply of energy on a nationwide basis;
- reducing greenhouse emissions and damage to the forests and grasslands;
- reducing State governance and launching sectoral privatization;
- expanding production capacities and increasing energy export earnings;
- substitution of the consumption of oil products by natural gas, particularly in powerplants;
- maximum possible utilization of the hydropower potential;
- energy conservation (through both supply and demand side management);
- modification of the energy pricing system;
- diversification of energy sources (including coal and renewable sources of energy to the Iranian energy mix); and,
- expanding research and technology in the oil, gas and electricity industries.

4. HYDROPOWER DEVELOPMENT

4.1 Background

4.1.1 History and development of hydro plants

Encompassing the Alborz and Zagros mountain ranges, the Iranian plateau has a vast potential for hydropower production. Iran has a potential production capacity of 50 TWh/year of hydropower. Studies show that the Karun catchment area has a potential capacity of 30 TWh/year, the Dez catchment area, 9 TWh/year and the Karkheh catchment area, 6 TWh/year. The remaining 5 TWh/year potential is provided by other catchment areas. Of the total potential capacity, only 7300 GWh/year have been put into operation.

4.1.2 First hydropower plants in Iran

• *Hamedan*

The first hydro plant in Iran was constructed in Hamedan city in 1929 by the German Kakamjin Freisch Company. The power generated was transmitted to Hamedan by 6300 V overhead lines.

• *Karaj (Amir Kabir)*

Iran's first major hydropower plant was the Amir Kabir dam powerplant. Its construction began in 1957 and it went into operation in 1961. The dam was constructed on the Karaj river in the Alborz mountain range with a catchment area of 764 million km^2 and an average annual surface runoff of 472 million m^3. It is a multipurpose scheme, built for flood control, the supply of 340 million m^3 of potable water to Tehran annually, and the production of 150 GWh/year of hydroelectric power to support the national grid, particularly

Table 3.5 – Renewable Energy Goals in the present Development Plan (2000-2004)

Small hydro	54.29 MW
Wind farms	91.5 MW
Geothermal plants	100 MW
Solar thermal plants (Parabolic Trough)	250 KW
Solar thermal plant (central receiver)	100 KW
Solar water heaters	1500 m^2
Fuel cells	209 KW
Photovoltaic	450 KW

during peak hours.

• *Dez dam*

Located 20 km northeast of Andimeshk city, Dez dam was the first large dam to be constructed in the Zagros mountain range. Its purpose is to supply 1800 GWh/year of hydroelectric power and to regulate water for irrigation purposes. It has a reservoir with a capacity of 3.5 billion m^3, a volume almost equal to that of the Tennessee Valley. The amount of water stored by the dam would be sufficient for the annual irrigation of 145 000 ha of the Khuzestan Plain. The construction work began in 1959 and was completed in 1962. The cost of the dam construction and the installation of generators and the irrigation network was US$ 106 million.

4.1.3 Types of project and organizations involved

The Iranian power industry came into existence almost a century ago in 1905, after the first urban power generation plant was put into operation by the private sector. In the first six decades of its life, the power industry was administered by the private sector. With the establishment of the Ministry of Water and Power in the 1960s, later changed to the Ministry of Energy in 1974, the formation and development of the National Grid was assigned to the Government due to the needs arising from the commissioning of the large hydropower plants of Dez and Amir Kabir.

The hydroelectric projects implemented in the past were limited to 13 in number, which were mostly executed by foreign companies. The feasibility studies of these projects were carried out by companies such as New York Development and Water Resources, Harza, Electroproject, Sir Alexander Gibb, Tractionnel of Belgium, Monenco, Acres International and Iran Development and Resources.

4.1.4 Environmental and economic aspects of hydro projects

• *Reductions in air pollution*

The generation of around 3000 GWh/year of electricity by a hydro plant such as Dez prevents the emission of 5.8 million kg of nitrogen oxides as a result of natural gas consumption by thermal powerplants, as well as 1700 million kg of carbon dioxide (greenhouse gas) in a year. The Rial value of the pollutants arising from the operation of thermal powerplants (substituting gas powerplants) is estimated at a minimum of 69 billion Rials/year (if natural gas is used as the fuel) and a maximum of 238 billion Rials per year (when a combination of diesel and natural gas is used as fuel).

• *Savings in fossil fuels*

For the production of the same amount of electricity which is generated by a 3000 GWh/year powerplant such as Dez dam, a gas plant would use around 900 million m^3 of natural gas. The construction of such a hydro plant not only replaces the need for the supply of this amount of natural gas by the national gas supply network, but also reduces the level of activities of the gas supply system.

• *Cultivation of downstream land*

The construction of dams has led to an increase in the land area under cultivation in downstream plains. Therefore, a corresponding increase can also be seen in agricultural production levels.

4.1.5 National grid development

A growth in the demand for power in the country, followed by a hasty development of the generation and transmission facilities, have been among the most prominent features of Iran's power industry in recent years. The maximum demand, which had hardly reached 3500 MW at the beginning of the Islamic Revolution (1978), increased to 23 000 MW during 2002 (nearly 6.5 times). The installed capacity of the powerplants across the country, which had stood at about 7000 MW, reached 29,000 MW, with an actual capacity of 26,500 MW during 2002 (nearly a fourfold increase).

The length of 63 kV to 400 kV transmission lines has increased from 16,000 km to 74,000 km, and the length of distribution and low voltage lines from 68,000 km to 460,000 km. At present, 100% of the urban population and 96% of the rural population are supplied by the national grid and enjoy an electric power supply. These figures show that in the years following the Islamic Revolution, the expansion of the power grid has exceeded the population growth in the country.

4.2 Current status of hydro plants

4.2.1 Operational hydro plants

The current installed capacity of hydropower plants is around 2000 MW, and their average energy production is 7300 GWh/year.

4.2.2 Hydro plants under construction

The main features of the hydropower plants under construction are given in Table 4.1.

4.2.3 Role of small hydro plants

As the production cost of small hydro plants is lower than that of other powerplants, and as they generate employment opportunities in rural areas of the country, the implementation of such plants is one of the power generation measures which have been fostered considerably by the Government. The Government's support has led to the construction of eight hydro plants in villages across the country. Nine other plants are under construction, and another 300 are being studied. One of the major goals of building small hydro plants is to supply power to irrigation wells, which will provide several economic advantages and lead to an economic boom in the agricultural sector.

4.2.4 Major companies involved in hydro plant construction

Iran Water and Power Resources Development Company (IWPC), affiliated to the Ministry of Energy, is in charge of the development of hydro plants, including large and medium-scale projects. There are 27 major Iranian contracting and consulting companies involved in the construction of hydropower plants (with expertise in the design and engineering of dams, tunnels and powerplants, and manufacturing of plant and equipment). A number of other foreign engineeers and manufacturers are working in the country.

4.2.5 Financing methods

At present, hydroelectric plants are 100% owned by the public sector. In the past, efforts were made to increase the plants' capacities using public funds. Now, however, in view of the heavy investment costs involved in this sector, efforts are being made to use foreign credits. The Japan Bank for International Cooperation (JBIC), for example, granted US$387 million to Iran from 1993 to 2002 for the construction of the Masjed Soleiman dam and hydropower plant with a capacity of 1000 MW. Also, The World Bank financed the construction of Dez dam in the 1960s. With the resumption of loan payments to Iran by The World Bank in 2000, there is hope that the Bank will finance more hydroelectric projects.

The resources required for the development of hydro plants include public revenue, the Ministry of Energy's internal resources, participation bonds, bank loans, and JBIC's financing and loan payment. The Iranian Government's next step involves achieving special foreign financial arrangements, such as a BOT (build, operate and transfer) contract for the Paresar powerplant. Nevertheless, because of the large volume of required investment and the long lead time of the implementation phase, the use of Government loans and finance is still recommended for hydropower plants.

4.2.6 Current changes in the hydro sector

Up to 2001, the Ministry of Energy was responsible for the development and operation of large hydro plants, and the Ministry of Agricultural Jihad for small (less than 2 MW) plants. In the Ministry of Energy itself, the development of large hydro plants has mainly been the responsibility of Iran Water and Power Resources Development Company (IWPC). The Khuzestan Water & Power Authority (KWPA) has been in charge of operating the large plants, which are mostly located in Khuzestan Province. Regional water and power companies have been responsible for the operation of other powerplants.

In view of the significance of hydropower plants in water resources management, IWPC and KWPA recently joined forces under the management of Iran Water Resources Development Organization. The responsibility for small hydro plants has been taken from the Ministry of Agricultural Jihad and given to Iran Water and Power Development Organization, which is run under the auspices of the Deputy Minister for Water Affairs in the Ministry of Energy.

4.2.7 Refurbishment activities

The repair and refurbishment of powerplants have been carried out by Iranian experts and technicians in accordance with international standards. Of the eight units at the Dez hydro plant, four have undergone basic repairs by powerplant personnel and a repair company. Of the four 250 MW units at the Shahid Abbaspour powerplant, two have undergone basic repairs and the other two are listed on the repair schedule.

As far as the renovation and repair of dams is concerned, the regional water authorities and the Water Resources Management Organization of the Ministry of Energy manage the dam monitoring as well as surveying and micro-geodetic work.

4.2.8 Environmental management: past experience and future plans

Currently, studies are being conducted on the environmental assessment of hydroelectric projects. Assessment reports on the environmental impacts of the Karkheh and Masjed Soleiman projects have been prepared and submitted to the Environmental Protection Organization. Comprehensive plans are being prepared which conform to environmental standards. The preparation of a management plan for the reduction of negative impacts of dam construction projects in the long term is the responsibility of the Ministry of Energy. Plant and animal species, and even human communities in the area of a reservoir may be adversely affected, to a certain extent, by dam construction. However, careful planning provides the possibility for new communities to settle in the area and special measures can be adopted for the protection of plant and animal species. The increase in the humidity in the area can help to develop the area's flora, and also increase human access to water, which is regarded as a vital and pivotal factor in economic and social development.

4.2.9 Public opinion of hydro projects

As the power generated by dams and hydropower plants is supplied to the national grid, the social effects (particularly on domestic consumers) and economic effects (on the industrial and agricultural sectors) of these projects cannot be examined independently. However, undoubtedly, the implementation of such projects will serve the purposes of sustainable development (improvement of the quality of life, development of the industrial, agricultural, and other sectors). These projects are very favourably received, because of their role in job creation in various fields such as the cement and metal industries, transport services, construction materials production and supply, machinery and spare parts production and repair, and powerplant equipment production. Another advantage is the employment of local manpower during the construction and operation phases. Estimates show that during the implementation of some hydro projects, about 5000 jobs have been created. Farmers also strongly support the hydro projects because of the resulting increase in the area of downstream land that can be cultivated, and the supply of regulated water during the low water seasons.

Among the major reasons behind public acceptance of such projects are the flood control role of Dez, Karkheh and Karun dams in the recent years and the supply of water during droughts to downstream farmers.

4.2.10 Major issues and challenges

The major challenges encountered in realtion to the development and operation of hydropower plants in Iran are:

- restricted financial resources for investment in new plants;
- relatively long construction phases, which discourage foreign investors from investing in hydro projects on a BOT basis;
- necessity for watershed management, to reduce sedimentation in reservoirs and increase their useful life;
- the need to maximize the use of domestic potential in the design and construction of projects, to stimulate job creation;
- large subsidies allocated within the energy sector, particularly in the oil and gas sectors, which in certain cases justifies the use of alternative powerplants, especially gas plants, instead of hydropower; and,
- greater attention needs to be given to environmental issues, and the environmental advantages of hydropower plants must be stressed in their economic assessment.

Table 4.1 – Hydro plants under constructions

Catchment	Potential		In Operation		Under Const.		Under Study	
	Cap'y (MW)	Energy (TWh/year)	Cap'y (MW)	Energy (TWh/year)	Cap'y (MW)	Energy (TWh/year)	Cap'y (MW)	Energy (TWh/year)
Karun	15,000	30	1,000	4	7,000	14,2	6,000	8
Dez	5,250	9	520	1,7	0	0	4,000	5,2
Karkheh	3,165	6	0	0	879	1,8	2,286	3,3
Other	1,036	5	480	1,1	201	0,4	358	0,7
Total	24,451	50	2000	6,8	8,080	16,4	12,644	17,2

4.3 Future status of hydro projects

4.3.1 Demand prediction

The annual growth in electric power consumption is predicted to be around 1200 to 1500 MW. The mean annual consumption growth for the short- and medium-term plans is predicted to be 6% and 5%, respectively. Demand was 24,000 MW in 2002, and is expected to increase to 28,000 MW by 2005, to 34,000 MW by 2010, and to 49,000 MW by 2020.

4.3.2 Potential in demand management

The power consumption management activities are divided into two main groups:

- measures which mainly cause a reduction in power consumption; and,
- measures which mainly cause a reduction in consumption peaks.

As a result, coordination with industries for load shifting and regulating the working hours of other businesses has been prioritized in connection with demand management.

4.3.3 Productivity development

Among the most important Government policies to increase productivity, reducing the construction costs of hydroelectric generation and the following achievements can be mentioned:

- enhancing the country's engineering capabilities for the construction of hydro powerplants;
- benefiting from past experiences in the erection of new plants;
- reducing the implementation time of projects;
- purchasing advanced equipment;
- selecting construction sites which involve lower construction costs; and,
- paying attention to secondary benefits and including the revenue from them in the total benefits of the projects (flood control, irrigation and potable water supply, con-

Table 4.2 – Hydropower plants under study

No.	Project (dam and plant)	Province	River	Type of dam	Height of dam(m)	Reservoir capacity (million m³)	Installed capacity (MW)	Mean annual energy (GWh)
1	Karun II	Khuzestan	Karun	CG	125	206	600	1950
2	Khersan I	Chahar mahal	Khersan	TGA	170	263	391	1218
3	Khersan II	Chahar mahal	Khersan	RD	120	2304	580	1689
4	Khersan III	Chahar mahal	Khersan	TCA	175	778	300	968
5	Bazoft	Chahar mahal	Bazoft	CA	160	262	163	487
6	Karun	Chahar mahal	Karun	RD	173	1176	452	826
7	Sazbon	Ilam	Seymareh	CGA	152	1609	500	797
8	Paalam	Ilam	Karkheh	CGA	156	3596	800	1278
9	Kuran Buzan	Lorestan	Seymareh	CFRD	134	2338	201	550
10	Tang-e-Mashureh	Chahar mahal	Kashkan	RCC	128	1019	166	500
11	Roudbar Lorestan	Lorestan Lorestan	Rudbar	RCC OR	169	285	400	1050
12	Bakhtiari	Lorestan	Bakhtiari	CA	260	4845	1220	2957
13	Lyro	Lorestan	Zalaki	CA	210	520	470	1045
14	Zalaki	Lorestan	Zalaki	CA	210	2517	466	1333
15	Sadasht	West Azarbaijan	Glass	CRD	126	1050	418	734
16	Shivashan	West Azarbaijan	Glass	RD	121	588	155	273
17	Siah Bisheh	Mazandaran	Chalus	RD	106	–	1000	1250

struction of recreational areas, development of the tourism industry, breeding of fish and other aquatic animals, and so on).

4.3.4 Potential for new projects

In the mid-1990s, the development of the country's hydroelectric potential was given top priority, with the construction of a number of new powerplants. To this end, based on the plans made, the implementation of new hydro plants, with a total capacity of 8000 MW of power was launched. Studies are also to be done for the production of a further 13,000 MW (Tables 4.2 and 4.3).

4.3.5 General direction of development

At present, the contribution of hydroelectric power to national electricity production is about 6%. The Ministry of Energy is trying to increase this share to 19% within the term of the Third and Fourth Economic Development Plans (up to 2005 and 2010, respectively). Therefore, the Ministry of Energy is seeking to increase the capacity of the powerplants within the next decade by 20,000 MW to 53,000 MW (see Table 4.4). The increase in the share of hydroelectric powerplants has special importance in terms of reducing environmental damage (by avoided fossil-fuel based generation), lower operational costs, and longer life of the facilities. For an arid and semi-arid country like Iran, the construction of hydro plants can lead to a number of secondary benefits such as water supply and flood control in addition to the primary goal of energy production.

4.3.6 Incentives for investment

Persuading the private sector to invest and also attracting foreign investment are also among the goals of the Ministry of Energy. The high volume of investment required for the development of the electrical industry has made dependence on domestic resources impossible.

Following the Cabinet's approval of the administrative regulations of the Foreign Investment Encouragement and Support Law, and the removal of obstacles in the way of foreign investment in the country, the use of this investment for the development of more production facilities will be possible. Also, the Ministry of Energy will issue licences to the private sector for the construction of powerplants and will guarantee to purchase the power. Pursuant to the Third Plan Law, the surplus electricity generated by units, which produce electricity for their own requirements, will be purchased at guaranteed prices. The Ministry of Energy can offer its powerplants, up to 10% of the national power generation capacity, for sale to the non-public sector at spot prices, demanding 40% of the price in cash and the rest in 5-year installments.

4.3.7 Future directions in the electricity sector

Table 4.3 – Under construction hydroelectric plants

No.	Project (Dam and Power plant)	Province	River	Type of dam	Height of dam(m)	Reservoir capacity (million m³)	Installed capacity (MW)	Mean annual energy (GWh)	Date of commercial operation
1	Masjed-e-Soleiman	Khuzestan	Karun	CRD	177	230	2000	3700	2002-2005
2	KhersanIII	Khuzestan	Karun	TCA	205	2750	2000	4137	2005
3	Karun I (Development)	Khuzestan	Karun	TCA	200	3139	1000	4000	2003
4	Karun IV	Chahar mahal-& Bakhtiari	Karun	TCA	230	2190	1000	2107	2006
5	Gotvand	Khuzestan	Karun	CRD	180	4500	1000	4500	2009
6	Karkheh	Khuzestan	Karkheh	CED	127	7300	400	934	2002-2003
7	Seymareh	Ilam	Seymareh	TCA	180	3200	480	850	2007

Table 4.4 – Future combination of electrical potential in Iran

Item	Type of plant	2005				2010				2020			
		Installed capacity		Energy production (GWh)		Installed capacity		Energy production (GWh)		Installed capacity		Energy production (GWh)	
		MW	%	MW	%	MW	%	MW	%	MW	%	MW	%
1	Steam	12,500	40,0			18,800	35,5			19,000	22,1		
2	Combined cycle	5,700	15,0			13,800	26			35,000	40,7		
3	Gas turbine	8,500	22,4	143,000	86.3	9,000	17	190,000	86	15,000	18,0	324,000	90
4	Diesel generator	400	1,1			400	1			400	0,5		
5	Nuclear	1,000	2,6	6,200	3,7	1,000	2	6,300	3	1,000	1,2	6,300	2
6	Hydropower	7,200	18,9	16,500	10	10,000	19	24,500	11	15,000	17,5	29,000	8
	Total	33,000	100	165,700	180	53,000	100	220,800	100	85,900	226	359,300	100

The most important policies of the electrical industry for the coming years can be summarized as follows:

- Restructuring and supporting the private sector's entry into the electrical industry.
- Reducing the State-run companies involved in the electrical industry and assigning the private sector the same work.
- Improving the load coefficient by controlling the increase in power demand and optimization of power consumption.
- Offering reasonable power supply prices, moving towards the cost price, and striking a sustainable balance in the power economy.
- Optimizing the power supply, with emphasis on reducing transmission losses, reducing distribution and internal consumption by powerplants, and enhancing the efficiency and performance of powerplants.
- Continuing the policy of replacing natural gas in powerplants, studying the possibility of using other fuels such as coal in power generation, and conservation of energy through the simultaneous production of electricity and heat.
- Developing the application of new forms of energy, with emphasis on localizing the technologies for production.
- Compiling a comprehensive plan for the energy sector, with emphasis on the electric power sector.
- Codifying the environmental standards of the energy sector in general, and of powerplant activities in particular.

5. CONCLUSION

Iran is a dry country with limited water resources. At the time being, the country's access to vast and inexpensive oil and gas resources, used in thermal powerplants, has overshadowed the development of hydro plants. It should not be forgotten that these oil and gas resources would be gradually depleted. On the contrary, energy production based on hydropower and other renewable resources can make a reliable investment for future generations. Therefore, a broad-based plan for hydropower development in Iran seems to be essential.

To this end, studies have been conducted for a comprehensive hydro plan for the country, based on a five-year survey plan in the various areas related to the country's river basins. Taking pumpedstorage plants into account, a total of 18,000 MW has been predicted in the survey plan. After completion of the survey studies, the best, most economical and most favourable technical criteria will be adopted, and will be implemented following adequate financing in the Third Plan and the attraction of various financial resources.

With the limited volume of oil and gas reserves and the ever increasing energy consumption, it is predicted that Iran will become an importer of oil products in the long term. Therefore, access to the technology of new renewables to be used in appropriate economic conditions, could serve as an appropriate solution to fossil fuel problems. Hydroelectric plants are environment friendly plants and could be used as multi-purpose facilities to serve such other goals as flood control and irrigation water supply. The availability of low cost and accessible fossil energy resources in Iran has been among the major reasons behind the limited attention given to hydroelectric energy in the past.

All in all, the issues of environmental pollution and the finite resource of fossil fuels contrast with the many advantages of hydroelectric powerplants. Thus, the renewable nature and abundance of hydroelectric energy in the country have attracted increased attention to this form of energy. This trend, which started in the First Economic and Social Development Plan, will continue to progress, as attested by the number of projects under way and those being studied.

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Ministerial Declaration recognizes the role of hydropower

Water & Energy was high on the agenda at the recent Third World Water Forum in Japan. On the opening day of the Forum in Kyoto, the First International Summit on Sustainable Use of Water for Energy took place. The Summit reviewed the relationships between water and energy, with a focus on hydropower, and was organized to follow-up the recommendations of the World Summit on Sustainable Development (WSSD, Johannesburg, 2002). Presentations covering integration of energy technologies, social/environmental good practice, investment and policy were covered in the programme, which included contributions by government representatives from Brazil, China, Egypt, Iran, Italy, Japan, Nepal, and Norway, together with United Nations, World Bank, utility, industry, education, research and NGO representatives.

The World Water Forum (16-23 March 2003) comprised 351 sessions in total, and these were convened in Kyoto, Shiga and Osaka. The entire Forum hosted 24,000 participants.

The Kyoto Ministerial Conference on 22/23 March formed the conclusion of the Forum. More than 170 countries were represented by Ministers and Heads of Delegation. The Ministerial Conference culminated in the ratification of a formal Declaration, which includes specific reference to hydropower:

(Item 15) "We recognize the role of hydropower as one of the renewable and clean energy sources, and that its potential should be realized in an environmentally sustainable and socially equitable manner."

The entire Kyoto Ministerial Declaration is available at the following URL:
http://www.world.water-forum3.com/jp/mc/md_final.pdf

Specific reference to hydropower in the Kyoto Declaration follows the recommendations given in the WSSD Implementation Plan (Item 19e) of Johannesburg last year, which call for increased use of all renewables, hydropower included. Both the Kyoto Declaration and the Johannesburg Implementation Plan are seen as essential mandates for the future role of hydropower. These significant statements support the following:

- Hydropower is renewable and clean.
- Renewables policy/legislation should include hydropower of all scales.
- Attempts to define hydropower as an "old" or "new" renewable are irrelevant.
- Hydropower's implementation (including refurbishment/upgrading) should be increased.
- According to the circumstances, there is a role for both large and small schemes.
- Environmental awareness and sensitivity to locally affected people are key aspects.
- The sector must continue to evaluate and promote good practice.

The International Hydropower Association (IHA) presented three documents at the Summit on Sustainable Use of Water for Energy in Kyoto:

- A volume of Country Reports, reviewing the past, present and future roles of water for energy in 16 countries (representing a cross-section of countries at different stages of development);
- A comprehensive review of the Role of Hydropower in Sustainable Development, with reference to major challenges such as freshwater management, global warming and poverty alleviation.
- Draft Sustainability Guidelines, presenting advice for IHA members involved in the implementation and management of hydropower. Prior to Kyoto, an extended group of organizations, including experts on environmental and social aspects, were invited to comment on the draft.

All the above documents are available from the IHA Central Office (see address given below).

A major outcome of the Summit was the commitment by IHA to promote hydropower-specific guidelines for planning, development and operation. The commitment was acknowledged by several government representatives and civil society groups. For example, the Dr Ute Collier of the Worldwide Fund for Nature recognized the Sustainability Guidelines as a good step forwards and gratefully acknowledged IHA's invitation to review the draft presented in Kyoto.

The Water & Energy theme for the Third World Water Forum was coordinated by IHA and included sessions independently organized by the International Rivers Network, Friends of the Earth (Japan) and the New Energy Foundation (Japan). The Summit and closing session for the theme were convened by IHA. The one-page Thematic Statement for Water & Energy, which was presented as an official input to the Ministerial Conference, can be found at either of the following URLs:

- *www.hydropower.org*
- *www.water4energy.net*
- *http://ap.world.water-forum3.com/themeWwf/en/themeShow.do?id=10*

Further information concerning IHA can be obtained from: International Hydropower Association Suite 55, Westmead House 123 Westmead Road Sutton, Surrey, SM1 4JH United Kingdom
Fax: +44 20 8770 1744
Email: iha@hydropower.org

HANOI, Vietnam (HCI)-Vietnam's Prime Minister Phan Van Khai has approved 62 power plants to be developed by 2011 by government utility Electricity of Vietnam and other developers. Forty-four of the plants are hydropower projects totaling 5,160 MW. EVN is to develop 20 hydro plants totaling 4,159 MW, while other entities are to develop 24 hydro plants totaling 1,001 MW,

(Source: HydroWorld Alert)

WASHINGTON (HCI)-The full U.S. House passed a national energy policy bill April 11 that contains hydro licensing reform language. The Senate Energy Committee endorsed similar language April 8. The measures would compel federal resource agencies to adopt a hydro license applicant's alternative license condition if it provides no less protection than the agency's own proposed condition.

(Source: Hydrowire)

WASHINGTON (HCI)-A federal court declared Alabama Power must obtain state certification under Clean Water Act Section 401 before it can replace turbine-generators that would increase the rate of water discharged from 154.2-MW Martin Dam into Tallapoosa River. The court said releasing more water could have negative water quality effects, such as low dissolved oxygen, that require 401 review.

(Source: Hydrowire)

KUALA LUMPUR, Malaysia (HCI)-Alstom has won a US$120 million contract to supply electro-mechanical equipment for the 2,400-MW Bakun Dam project on Malaysia's Sarawak Island. Alstom is to supply four turbine-generators and other equipment. Developer Sarawak Hidro previously awarded Bakun's civil works constract to a consortium of Malaysian and Chinese firms headed by Sime Darby of Malaysia.

(Source: HydroWorld Alert)

WASHINGTON (HCI)-American Rivers Inc. targeted hydro operators on three of its top 10 "most endangered" rivers of 2003. The group accused: PacifiCorp's 151-MW Klamath River project of harming the Klamath in Oregon; Idaho Power's 1,166.5-MW Hells Canyon project of harming the Snake River in Idaho; and Alabama Power'sd 135-MW R.L. Harris Dam of harming the Tallapoosa River in Alabama.

(Source: Hydrowire)

BEIJING (HCI)-Builders of 18,200 MW Three Gorges Dam blocked China's Yangtze River June 1, starting to fill the reservoir of the world's biggest hydroelectric project. Nineteen of 22 gates at Yichang closed to create a 600-kilometer reservoir. Two of 26 units are to begin generating in August. Three Gorges is China's biggest engineering project since the 2,000-year-old Great Wall of China.

(Source :HydroWorld Alert)