Mohan Munasinghe

Planning for Electrical Power: Costs and Technologies

AN INTERVIEW WITH AN ENERGY SPECIALIST

Planning for electrical power: costs and technologies

Dr. Munasinghe, an architect and economic planner for the World Bank, expresses his opinions on planning of new generation facilities and the potential uses of the new energy technologies in rural areas.

Q Dr. Munasinghe, how do planners justify rural electrification, that is, supplying power to groups who cannot afford it?

MUNASINGHE: I think in many developing countries, and even in a country like the United States, you'll find disadvantaged sections. There may be poor groups or areas of a country that are depressed and regions that need to be developed. Now, if you ask the conventional questions for expanding the system, such as, do these people have enough money to pay for the electricity, and so on, you might not supply them with it simply because they are too poor, they don't have the equipment, and it's just too costly to supply them with it.

However straightforward fairness and equity considerations, as well as political considerations, might dictate that you make an effort to provide these areas with electricity as some basic requirement. Then you have to target your electric power.

Now, rural electrification is a very good example. In many countries, planners are forcing the pace of rural electrification. And, they're targeting it to specific areas at considerable cost to the country. Nevertheless, decision makers feel that this is justified—we have to electrify these areas, we have to give power to these people.

The opinions expressed in this interview are those of Dr. Munasinghe and do not necessarily reflect the policies of the World Bank or affiliated organizations.

Dr. Mohan Munasinghe, an engineer economist, Energy Department of the World Bank, has achieved international recognition in the fields of power and energy. Trained in electrical engineering, solid state physics, and economics, the 34-year-old architect and planner earned degrees at Cambridge, Massachusetts Institute of Technology, and McGill and Concordia Universities in Canada. He has taught and lectured widely, and he has published 35 papers on energy-related topics. Johns Hopkins Press (Maryland, USA) recently released Economics of Electric Power System Reliability and Planning. A second book, Electricity Pricing in Developing Countries will be available sometime this year.

The World Bank and International Development Association have committed some US$1.2 billion towards electric power systems. In this interview, Dr. Munasinghe expresses his own views on some of the technical aspects involved. Dr. Munasinghe was interviewed for NATIONAL DEVELOPMENT by Julian Weiss, a freelance journalist.
How is this handled?

MUNASINGHE: Well, there are three aspects here. First of all, you have to be careful. Very often, if the rural electrification scheme is not properly policed, the local merchants of government officials and so on get electricity to their homes and the vast mass of the peasantry do not benefit. So, unless the electricity supplied to rural areas is coordinated or integrated with other aspects of rural development, all the people do not feel the full benefit.

In fact, when you supply electricity, you’ve got to make sure that not only do the rich get connected, but also the poor. So the connection policy is very important. For example, if the connection deposit happens to be six months’ income for the poor man, he’s not going to be able to do it. You might tell this man, look, I’ll connect you, but you can pay over the next ten years. The connection policy must be humane.

Second, the cost of electricity must be reasonable. I don’t mean that you have to subsidize all electricity, but you might determine that for a family of five or six, x-amount of electricity per month is required to run a few light bulbs, an electric iron, and some bare necessities. Now, with that amount of electricity, a block of 50 kW/hrs a month, for example, you might have a subsidized rate, and if the family consumes more than the 50 kW/hrs, then they pay the full rate. So, the really poor people who use the bare minimum will have the advantage of the subsidized rate, whereas the better-off people, who tend to use more and who don’t mind paying, will pay a larger amount for the higher blocks of electricity. In the United States, this is called the lifeline rate policy.

The third and last aspect of targeting is quality of supply. In other words, if you want to supply electricity to a large number of relatively disadvantaged people, for example, then you might want to supply it at some minimum level of quality of supply and standard, that is, build your system cheaply so you can reach a large number of people. On the other hand, if you’re going to supply an industrial customer who needs a reliable system, you build a more reliable system.

Ultimately, the cost and the price would be commensurate with the type and size of system you build.

NATIONAL DEVELOPMENT: How far into the future is it necessary to forecast?

MUNASINGHE: This depends principally on the purpose of your forecast. Long-range forecasts should be at least ten years into the future for power system planning. In this case, the main determinant of the time period for forecasting is the gestation period of new projects. For example, if you have a hydro-electric project, it could take as much as eight years from inception to completion. Nuclear projects may take even longer.

Then you have short- and medium-range forecasting. Short-range forecasting may be as short as one year. Here the emphasis is on how best to utilize those existing facilities, rather than on building new ones. For example, you may have a hydro-electric system, where water is collected in a reservoir during the rainy season. Now, you have to use this water throughout the year, and depending on how you predict the demand on a day-to-day and a week-to-week basis, you would draw off the water from the reservoir. Thus, you might want to empty it suddenly at the beginning, or you might want to save it for the end of the year. This kind of short-range forecasting is mainly for husbanding existing resources.

The emphasis, however, should be on the long-range forecast because as the costs of energy rise, the costs of building new facilities becomes a dominant consideration.
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NATIONAL DEVELOPMENT: And of course, this has a bearing on determining the pricing policy.

MUNASINGHE: On the issue of demand estimation and the amount of electricity and energy that is required, one of the very crucial factors that one has to look at are the price levels. It is not sufficient really to look at the physical requirements of electricity without relating it to the price, as you well know from the gasoline consumption in the United States. As soon as the price was raised above US$1.00 per gallon, the problems of congestion and gas lines eased. So, you have to make a reasonable projection of your price levels before you do your demand forecasting, as well as your system planning.

The pricing policy that is followed is a very crucial parameter, simply because if you provide electricity too cheaply, you will overstimulate demand in times when energy is very expensive. In other words, if you give it away free, people are going to use it—this is an enormous burden to supply. So the pricing policy must be such that it is a signal to the consumer, either that electricity is cheap or that it's expensive.

Pricing must be future-oriented. If you expect oil prices to go up significantly, your electricity costs will follow that long-run tendency. If you don't set prices to tell consumers what it will cost to generate electricity in the future, you're misleading them. You're also misleading industrial people because they may set up plants that use a lot of electricity under the mistaken belief that electricity is cheap, whereas if you had given them the right price signal, they would have gone to some other form of energy.

Another aspect I wanted to emphasize was that in the least-cost approach to planning, traditionally, one looked only at the system cost—the cost of supplying electricity. But I think one has to go beyond that and also look at the impact of electricity on consumers because our old friend, quality of supply, creeps in through the back door.

We know, for example, that power shortages impose costs on society. The New York power failure is a classic example. Here, the total cost for a day or half a day of power failure is something like US$350 million—using a recent estimate.

The trade-off is the following: If you build a system in a very robust way and in a very reliable way, the incidence of power failures will be low; therefore, the costs imposed on customers by the power failure will also be low. But the costs of building the system are high. On the other hand, if you build a very cheap system, the costs of building it will be low, but when the lights go out every so often, the costs imposed on customers will be very high. So it's not simply a question of minimizing the cost of supply.

You have to minimize the total social costs, not only the system cost. This is a new concept of planning that has become very attractive in the 70s...it's one of my favorite themes. In fact, I've written a book on the topic. The idea is that you have to look at system planning from a national or society's point of view—you have to minimize not only the cost of producing the power, but you also have to minimize the cost of power failures to the customer. So there is the additional cost dimension that has to be incorporated into the criteria for system planning.

**Q** Are there other factors that planners should take into account?

MUNASINGHE: Well, perhaps I overemphasized the cost criterion. Cost is the principal criterion, but there are many others. For example, one would want to go with a proven technology—one that does not have significant teething problems. There is, for example, a tendency now to move away from electricity generation through burning oil, simple because of the high cost of oil. And people are moving towards the use of coal and geothermal technology.

But in many developing countries, some of the technologies may be unfamiliar. We have to have a training period—build small-scale facilities and build up the expertise. This is one of the considerations.

Then there is also the question of scale with certain types of facilities, for example, nuclear. There is a minimum unit size that is economically viable, say 600 MW. Now, in a system that is small, in a relatively small country, the total demand for the whole system may be of the same order of magnitude. So if you have a 500 MW system, that is, with 500 MW peak demand, adding a nuclear power plant to the system is simply not sensible. First, you're adding much more generating capacity than will be required

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*Mohan, Munasinghe, The Economics of Power System Reliability and Planning (Baltimore, Maryland, USA: John Hopkins Press), 1979.*

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for a considerable time in the future. And second, if that power plant for some reason would have to shut down, you'd lose a large chunk of your available capacity. So, there are additional considerations—technical and other—beyond the least cost which do apply.

Given all these constraints, the overall trend is a shift away from oil-burning facilities towards hydro. Hydro is becoming very popular in the sense that many hydro-electric dam sites which were examined in the past and were dismissed in the days when oil was US$2.00 a barrel are now being critically re-examined and found to be economically viable now that oil is more than ten times that price.

There is also a push towards using coal. Most recently, people are finding indigenous deposits in many Third World countries. Some of them are relatively low-grade, which in the past may have been simply ignored because oil was cheap. Of course, there are the new technologies like geothermal, which are also being pursued—but with some caution, because they are not quite proven—they are emerging.

What, specifically, are some of the emerging technologies, and where and how can they be applied?

Munasingshe: I will address the question of new technologies directly—we can split it into two. There are immediate possibilities—within the next five or ten years. For example, tidal power in countries where there is a significant tidal force (the French and the Canadians, I believe, have already developed economically viable tidal power stations and are using them) is a strong possibility. Tidal power is more appropriate for the temperate zones because near the equator you don't get large tidal flows.

Wind power is also a current area where there has been significant development and operation of facilities. Wind generation is particularly effective in countries which have large shore areas or mountainous areas where you have continuous wind blowing. Similarly, solar power will come into its own, I think, in the next five years or so, because the costs of solar cells that convert sunlight to electricity have dropped by a factor of ten in the last five years and they are going to continue to drop at this rate; also in the next five years, it should become economically viable. But again, you have to have a country where you have a large number of days of full sunlight.

These technologies depend on resource endowment, and also require some kind of storage facilities because tidal, wind, and solar power all are intermittent. So what you do is use the generator to produce electricity when the resource is available and store it in a battery for use when it's not available. And I think in addition to developing these sources, one also has to develop the storage capabilities, i.e., batteries or some other form of storage—but I would call these short-term possibilities in selected areas.

Also, in the old days there were many so-called windmills, watermills, and so on, which generated electricity independently when we did not have these big power systems. Then, as the big power systems came in, those little sites were neglected and people just hooked onto the main grid. But now people are finding that the price of electricity is so high that it might be worthwhile running their little generators again. For instance, depending on the site and the location, mini-hydro could become very viable—the technology exists, so it is basically a question of economics.

In terms of the next step, we have other types of [emerging] technologies which will take more than a decade to develop. These include wave power technologies which would use the wave motion of a large body of water like the ocean to generate electricity. There is also something called OTEC (Ocean Thermal Electricity Conversion), which uses thermal gradients in the ocean. OTEC would be mostly appropriate for the tropical regions because you need a large heat gradient or temperature difference.

There is also a type of technology called fuel cells which use some kinds of natural gas or some other gas to convert it directly to electricity with a high degree of efficiency, and so on.

Now, there's one qualifier I want to add—that each of these newer technologies cannot by itself support the full supply of power. At best, it can supplement existing major sources of power which have already been exploited. So maybe they can supplement up to 25%—but it's only a supplement—it's not a total solution to the shortage of power.

What are the choices for the major sources of power then, and how are they selected?

Munasingshe: In terms of generation, the main choice is between hydro-electric power systems and
thermo-electric generation. The principle criterion we use, as always, is an economic one—what is the cheapest way of producing electricity in the long term. I must emphasize the long term, and perhaps exemplify it to the comparison of hydro versus thermal because usually hydro-electric facilities have a high capital cost. In other words, it's expensive to build a hydro-electric station because generally they are in remote, mountainous areas. But once it's built, running a hydro-electric station is very cheap. It's practically zero cost because the water is free.

On the other hand, the cost of building a thermo-electric power station is not so high as the hydro because usually it is built near an urban center or some place like that and the capital costs are not high. However, the operating costs are going to be very high because every year you burn fuel and the fuel costs are going to mount up.

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So if you compare a hydro station with a thermal station, over a short period of time, say, two or three years, obviously, the thermal station is going to look very favorable. But over a long period of time, say, 50 years, hydro is going to look very favorable.

Of course, there is also the effect of discounting because future costs are discounted. This is technical, but the point is that the principle criterion used in the choice of generation technology is the least-cost criterion.

Q Do different criteria apply to rural electrification schemes than to urban?

MUNASINGHE: Well, the question I think can be answered in two parts. One is that the standards of supplying rural electricity may not be the same standards you would use in urban areas. For example, I think one of the principle factors is the quality of supply. If you were supplying an industrial customer or a dense residential area in a town, you’d want to make sure that your supply of electricity was reasonably reliable. Whereas if you were supplying a very remote rural area, you may not want to supply electricity of the same quality.

The reason is that there is a price tag attached to quality. The more reliable your supply, the more expensive it is. And initially, the cost of rural electrification is so high, and since investment funds are limited, it may make more sense to put up a fairly simple system and supply more customers rather than to build a gold-plated or robust system and only be able to supply a few people. Simply because in rural areas, those customers may not care much if the lights go out, whereas in the urban area, if that happens, people start jumping up and down.

The second aspect concerns the actual technology. Currently, the conventional items of equipment are used in urban areas as well as rural—there would be no new equipment. You’d use the same types of wire, the same types of transformers, but not necessarily the same unit sizes (i.e., you might use bigger transformers in urban areas). Nevertheless, the same type of equipment and technology would be used. What could be different in the future in the case of rural electrification is the use of some newer technologies for isolated generation—solar cells, wind power, and mini-hydro—can play a very effective role in rural electrification and those new technologies may in fact provide electricity to many rural areas where it is not economical to provide service from a central grid.

Q What happens to the isolated generators when demand increases?

MUNASINGHE: Over time, there is a growth of demand in these local areas, and eventually, you’d want...
to hook the customers up to the main grid. The demand would justify running an extra length of transmission and joining these people to the main grid. Now, what happens to all the isolated sources of power that were operating before the main grid came in? In the traditional process, the main grid supply was so much cheaper that the local sources were simply suppressed, or allowed to decay.

Now it will be possible to interchange power between the main grid and some of these other sources. The economics of the situation are such that, if you already have an existing generating site like a mini-hydro site, it might be worthwhile to keep it running. The advantage of having the main grid is that then you do not need storage facilities at isolated sites. In other words, if you hook onto the main grid, you can snap on your light and have power all the time. If you hook up the two, when you have wind, you're generating wind power and you might have an excess of supply, right? That excess supply could be fed back into the main grid and that way it would be possible to supplement the supply available to the main grid.

Essentially, it's an exchange of power and the main grid functions as your storage medium. Now the difficulty, if at all, is the technical means of exchanging power between a main grid and a small facility. You have to have metering to know when the small source is supplying power to the grid and when the grid is supplying power to the small source. But I think this can be surmounted.

Q Are there advantages in efficiency in using the power grid system as opposed to local generation?

MUNASINGHE: Yes, but this must be developed in a historical context. If the local systems in several towns interconnect, then you have the rudiments of a power system. Now, with the idea of interconnection, there are two concepts. One is economies of scale. If you have two or five towns interconnected, the power stations that you build could be much larger. And you can build and operate a larger power station more cheaply. It's like buying a giant tube of toothpaste—you can buy it cheaper per unit than if you buy, say, 10 small tubes.

The second factor is reliability—that is, suppose you have five towns connected as opposed to five towns each having its own power station or generator. In an isolated town, if the generator fails, all the lights go out. But if the towns are interconnected, another town might have enough surplus at the margin to supply the blacked-out city with electricity. This is the concept of saving on the reserve margin. And if you have a large system, your individual reserve margin can be that much smaller because you know there are many, many units distributed and if one fails you can draw power from the other, which is a kind of economy.

NATIONAL DEVELOPMENT: In the literature I've seen from the Bank, reference is made to regions for electrification rather than to cities, towns, or other divisions. Are there technical advantages to regional interchanges on power grids?

MUNASINGHE: Technically, yes, because the nation-state is a political unit, so the idea of an interconnected system for one country bounded by the geographic confines of that country are simple based on the concept of the nation-state. But if there are two adjacent countries and they are on friendly terms, there is no reason why they should not exchange power through an interconnection and thereby realize further economies of scale. In fact, where it is politically and institutionally feasible, I think regional interconnection should be pursued.

Of course, it can be done at various levels. In the United States, for instance, groups of states have exchanged facilities for electric power. When one has a deficit, it can borrow from the other. The degree of interconnection is relatively weak in some cases and is done on a contractual basis. You say, every year from month A to B, I will supply you with x-amount of power. Over the other part of the year, you will return it to me. If there's a balance, we'll pay some agreed sum for it.

A full interconnection will imply that there is free flow of power between the two countries—free not in the economic sense, but physically unimpeded.

You would have metering and you would not know beforehand which way the balance would be, but most countries would have confidence that together they would have sufficient power to supply the combined needs of both countries, and they would settle the balance later at some agreed price. So the degree
of interconnection depends on the institutional and political relationship between the two countries. In short, there are advantages to regional integration provided the technical parameters are favorable.

**Q**

What do you mean by favorable technical parameters?

MUNASINGHE: Well, you have broad areas of the world where technical standards are somewhat different. For example, in America, the standard is 110 or 115 volts for domestic supply, at 60 cycles per second, and it is usually a single-phase system. But in most of Europe, Africa, and Asia, you have 230-volt systems, at 50 cycles per second. In fact, there are some countries where more than one system co-exists. This is very costly. For example, in Saudi Arabia, part of the system was built by the British and another has an American influence, so you have two different sets of systems. When the stage is reached to interconnect them, a decision will have to be made: Do we go with one set of standards or the other? [Editor’s note: See accompanying chart, outlining the various systems around the world.]

**Q**

Well, are there applications, other than country to country interconnection, for interchanging power?

MUNASINGHE: Yes, and it comes under the name of co-generation. In fact, the concept has been developed for application to conventional technologies in urban areas. For example, in Europe you have industrial installations that develop or have to use large amounts of steam for heating. Some of them produce their own electricity for use within the plant. It makes a lot of sense for them to have a hookup with the main power system so that instead of shutting off their electricity generation and steam plants at night and starting them up during the day—which might be wasteful—they can keep running them continuously, and when they do not need the power for their own use, they can feed it into the grid. And, if they have a deficit of generation at a particular time, they can draw power from the grid.

There is not only exchange of electricity but also exchange of heat. Often, waste heat is produced by industrial concerns, and this is used in many towns for heating neighboring houses. So the concept of sharing energy is developing very rapidly and the technical problems are rapidly being overcome.