Renewable and Efficient Electric Power Systems

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Solution. They both have the same energy costs: 100,000 kWh/mo × \$0.06/kWh = \$6000/mo

Using (5.1), the peak demand for A is

$$\text{Peak(A)} = \frac{100{,}000 \text{ kWh/mo}}{15\% \times 24 \text{ h/day} \times 30 \text{ day/mo}} \times 100\% = 925.9 \text{ kW}$$

which, at \$10/kW-mo, will incur demand charges of \$9259/mo.

The peak demand for B is

$$\text{Peak(B)} = \frac{100{,}000 \text{ kWh/mo}}{60\% \times 24 \text{ h/day} \times 30 \text{ day/mo}} \times 100\%$$
$$= 231.5 \text{ kW} \qquad \text{costing } \$2315/\text{mo}$$

The total monthly bill for A with the poor load factor is nearly twice as high as for B (\$15,259 for A and \$8315 for B).

5.2.6 Real-Time Pricing (RTP)

While time-of-use (TOU) rates attempt to capture the true cost of utility service, they are relatively crude since they only differentiate between relatively large blocks of time (peak, partial-peak, and off-peak, for example) and they typically only acknowledge two seasons: summer and non-summer. The ideal rate structure would be one based on real-time pricing (RTP) in which the true cost of energy is reflected in rates that change throughout the day, each and every day. With RTP, there would be no demand charges, just energy charges that might vary, for example, on an hourly basis.

Some utilities now offer one-day-ahead, hour-by-hour, real-time pricing. When a customer knows that tomorrow afternoon the price of electricity will be high, they can implement appropriate measures to respond to that high price. With the price of electricity more accurately reflecting the real, almost instantaneous, cost of power, it is hoped that market forces will encourage the most efficient management of demand.

5.3 ENERGY ECONOMICS

There are many ways to calculate the economic viability of distributed generation and energy efficiency projects. The capital cost of equipment, the operation and maintenance costs, and the fuel costs must be combined in some manner so that a comparison may be made with the costs of not doing the project. The treatment presented here, although somewhat superficial, is intended to provide a reasonable start to the financial evaluation—enough at least to know whether the project deserves further, more careful, analysis.

5.3.1 Simple Payback Period

One of the most common ways to evaluate the economic value of a project is with a simple payback analysis. This is just the ratio of the extra first cost ΔP to the annual savings, S:

$$\text{Simple payback} = \frac{\text{Extra first cost } \Delta P(\$)}{\text{Annual savings S}(\$/\text{yr})} \tag{5.2}$$

For example, an energy-efficient air conditioner that costs an extra $1000 and which saves $200/yr in electricity would have a simple payback of 5 years.

Simple payback has the advantage of being the easiest to understand of all economic measures, but it has the unfortunate problem of being one of the least convincing ways to present the economic advantages of a project. Surveys consistently show that individuals, and corporations alike, demand very short payback periods—on the order of only a few years—before they are willing to consider an energy investment. The 5-year payback in the above example would probably be too long for most decision makers; yet, for example, if the air conditioner lasts for 10 years, the extra cost is equivalent to an investment that earns a tax-free annual return of over 15%. Almost anyone with some money to invest would jump at the chance to earn 15%, yet most would not choose to put it into a more efficient air conditioner.

Simple payback is also one of the most misleading measures since it doesn't include anything about the longevity of the system. Two air conditioners may both have 5-year payback periods, but even though one lasts for 20 years and the other one falls apart after 5, the payback period makes absolutely no distinction between the two.

5.3.2 Initial (Simple) Rate-of-Return

The initial (or simple) rate of return is just the inverse of the simple payback period. That is, it is the ratio of the annual savings to the extra initial investment:

$$\text{Initial (simple) rate of return} = \frac{\text{Annual savings S } (\$/\text{yr})}{\text{Extra first cost } \Delta P(\$)} \tag{5.3}$$

Just as the simple payback period makes an investment look worse than it is, the initial rate of return does the opposite and makes it look too good. For example, if an efficiency investment with a 20% initial rate of return, which sounds very good, lasts only 5 years, then just as the device finally pays for itself, it dies and the investor has earned nothing. On the other hand, if the device has a long lifetime, the simple return on investment is a good indicator of the true value of the investment as will be shown in the next section.

Even though the initial rate of return may be misleading, it does often serve a useful function as a convenient "minimum threshold" indicator. If the investment has an initial rate of return below the threshold, there is no need to proceed any further.

5.3.3 Net Present Value

The simple payback period and rate of return are just that, too simple. Any more serious analysis involves taking into account the time value of money—that is, the fact that one dollar 10 years from now isn't as good as having one dollar in your pocket today. To account for these differences, a present worth analysis in which all future costs are converted into an equivalent *present value* or *present worth* (the terms are used interchangeably) is often required.

Begin by imagining making an investment today of P into an account earning interest i. After 1 year the account will have earned interest iP so it will then be worth $P + iP = P(1 + i)$; after 2 years it will have $P(1 + i)^2$, and so forth. This says that the future amount of money F in an account that starts with P, which earns annual interest i over a period of n years, will be

$$F = P\ (1 + i)^n \tag{5.4}$$

Rearranging (5.4) gives us a relationship between a future amount of money F and what it should be worth to us today P:

$$P = \frac{F}{(1 + i)^n} \tag{5.5}$$

When converting a future value F into a present worth P, the interest term i in (5.5) is usually referred to as a discount rate d. The discount rate can be thought of as the interest rate that could have been earned if the money had been put into the best alternative investment. For example, if an efficiency investment is projected to save \$1000 in fuel in the fifth year, and the best alternative investment is one that would have earned 10%/yr interest, the present worth of that \$1000 would be

$$P = \frac{F}{(1 + d)^n} = \frac{\$1000}{(1 + 0.10)^5} = \$620.92 \tag{5.6}$$

That is, a person with a discount rate of 10% should be neutral about the choice between having \$620.92 in his or her pocket today, or having \$1000 in 5 years. Or stated differently, that person should be willing to spend as much as \$620.92 today in order to save \$1000 worth of energy 5 years from now. Notice that the higher the discount rate, the less valuable a future payoff becomes. For instance, with a 20% discount rate, that \$1000 in 5 years is equivalent to only \$401.87 today.

When viewed from the perspective of a neutral decision—that is, would someone be just as happy with P now or F later—the discount rate takes on added meaning and may not refer to just the best alternative investment. Ask people without significant financial resources—for instance, college students—about the choice between \$621 today or \$1000 in 5 years, and chances are high that they would much prefer the \$621 today. In 5 years, college students anticipate having a lot more money, so \$1000 then wouldn't mean nearly as much as \$621 today when they are so strapped for cash. That is, their personal discount rate is probably much higher than 10%. Similarly, if there is significant risk in the proposition, then factoring in the probability that there will be no F in the future means that the discount rate would need to be much higher than would be suggested by the interest that a conventional alternative investment might earn. Deciding just what is an appropriate discount rate for an investment in energy efficiency or distributed generation is often the most difficult, and critical, step in a present value analysis.

Frequently, a distributed generation or efficiency investment will deliver financial benefits year after year. To find the present value P of a stream of annual cash flows A, for n years into the future, with a discount rate d, we can introduce a conversion factor called the *present value function* (PVF):

$$P = A \cdot \text{PVF}(d, n) \tag{5.7}$$

For a series of n annual \$1 amounts that start 1 year from the present, PVF is the summation of the present values:

$$\text{PVF}(d, n) = \frac{1}{1+d} + \frac{1}{(1+d)^2} + \cdots + \frac{1}{(1+d)^n} \tag{5.8}$$

A series analysis of (5.8) yields the following:

$$\text{PVF}(d, n) = \text{Present value function} = \frac{(1+d)^n - 1}{d(1+d)^n} \tag{5.9}$$

With all of the variables expressed in annual terms, the units of PVF will be years.

The present value of all costs, present and future, for a project is called the *life-cycle cost* of the system under consideration. When a choice is to be made between two investments, the present value, or life-cycle cost, for each, is computed and compared. The difference between the two is called the *net present value* (NPV) of the lower-cost alternative.

Example 5.6 Net Present Value of an Energy-Efficient Motor. Two 100-hp electric motors are being considered—call them "good" and "premium." The good motor draws 79 kW and costs \$2400; the premium motor draws 77.5 kW and costs \$2900. The motors run 1600 hours per year with electricity costing \$0.08/kWh. Over a 20-year life, find the net present value of the cheaper alternative when a discount rate of 10% is assumed.

Solution. The annual electricity cost for the two motors is

$$A(\text{good}) = 79 \text{ kW} \times 1600 \text{ h/yr} \times \$0.08/\text{kWh} = \$10{,}112/\text{yr}$$
$$A(\text{premium}) = 77.5 \text{ kW} \times 1600 \text{ h/yr} \times \$0.08/\text{kWh} = \$9920/\text{yr}$$

Notice how the annual energy cost of a motor is far more than the initial cost.

The present value factor for these 20-year cash flows with a 10% discount rate is

$$\text{PVF}(d, n) = \frac{(1+d)^n - 1}{d(1+d)^n} = \frac{(1+0.10)^{20} - 1}{0.10(1+0.10)^{20}} = 8.5136 \text{ yr}$$

The present value of the two motors, including first cost and annual costs, is therefore

$$P(\text{good}) = \$2400 + 8.5136 \text{ yr} \times \$10{,}112/\text{yr} = \$88{,}489$$
$$P(\text{premium}) = \$2900 + 8.5136 \text{ yr} \times \$9920/\text{yr} = \$87{,}354$$

The premium motor is the better investment with a net present value of

$$\text{NPV} = \$88{,}489 - \$87{,}354 = \$1{,}135$$

The net present value calculation can be simplified by comparing the present value of all of those future fuel savings ΔA with the extra first cost of the more efficient product ΔP.

$$\text{NPV} = \text{present value of annual savings} - \text{added first cost of better product}$$
$$\text{NPV} = \Delta A \times \text{PVF}(d, n) - \Delta P \tag{5.10}$$

Using (5.10) with the data in Example 5.6 gives

$$\text{NPV} = (\$10{,}112 - \$9920)/\text{yr} \times 8.5136 \text{ yr} - (\$2900 - \$2400) = \$1135$$

which agrees with the example.

5.3.4 Internal Rate of Return (IRR)

The *internal rate of return* (IRR) is perhaps the most persuasive measure of the value of an energy-efficiency or distributed-generation project. It is also the trickiest to compute. The IRR allows the energy investment to be directly compared with the return that might be obtained for any other competing investment. IRR is the discount rate that makes the net present value of the energy investment equal to zero. In the simple case of a first-cost premium ΔP for the more efficient