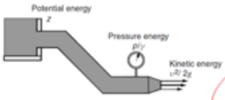
1. Describe how a Run-of-the-rive mini hydro power plant works. Micro-Hydro 微型水电

Run-of-the-river (ROR) hydro power plants generate electricity using the natural flow of a river, without requiring a large dam or reservoir. Key steps in the operation:

The energy associated with water manifests itself in three ways:
as potential energy (mgz due to the water level in the dam) pressure energy (pV in the penstock) and kinetic energy ($\frac{1}{2}mv^2$ as water flows).



2. A Run-of-the-river mini hydro power plant has following operational parameters. 径流式电站 水库

Water Flow rate = 1000 litres/min $1m = 100cm$

Height difference between source of water and the location of the turbine/generator = 50 meter $1cm = 10mm$

Length of the PVC pipe = 100m

Diameter of the PVC pipe = 100mm $= 0.1m$

Efficiency of the turbine/generator combined = 50%

$1m^3 = 1000L$.

a) What is the power output of the plant neglecting the losses in the PVC pipe?

b) How much energy will be produced in a month if the PVC pipe friction loss is 20%?

$$Power = \frac{Energy}{Time} = \frac{Weight}{Volume} \times \frac{Volume}{Time} \times \frac{Energy}{Weight} = \rho g Q H$$

where,
Power in (*W*)
ρ is density (Kg/m^3)
g is gravitational acceleration (m/s^2)
Q is volume flow rate (m^3/s)
H is the head (m)

$g = 9.81 m/s^2$

Energy head, $H = z + \frac{p}{\gamma} + \frac{v^2}{2g}$ 单位 = m.

where, 能量除以液体的重量 单位质量的能量

z is the elevation above a reference height (m),
p is the pressure (N/m^2),
γ is specific weight (N/m^3), $\gamma = 9810 N/m^3$
v is the average velocity (m/s)
g is gravitational acceleration (m/s^2)

$A = \frac{\pi}{4}D^2 = \frac{\pi}{4} 0.1^2 m^2$

assume 20% loss

a) $P = \eta \cdot \rho \cdot g \cdot Q \cdot H \rightarrow 50 \times 0.8 = 40m$

$\eta = 0.5$ ρ = water density ($1000 kg/m^3$)

$Q = 1000 L/min = 1000/60 = 16.67 L/s = 0.01667 m^3/s$

$\therefore P = \sim$

$V = \frac{Flow(\frac{Litres}{min}) \times 10^{-3}}{60 \times A(m^2)}$ m/sec

$V = \frac{1000 \times 10^{-3}}{60 \times \frac{\pi}{4} \times 0.01} = 2.12 m/s$

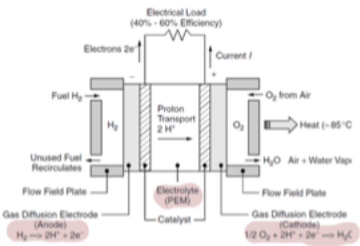
$H = z + \frac{P}{\gamma} + \frac{v^2}{2g} = 50 + \frac{P}{\gamma} + \frac{v^2}{2g}$

b) Friction loss reduces efficiency to $0.5 \cdot (1-0.2) = 0.4$ $P = P \cdot \frac{0.4}{0.5} =$ ___

$E = P' \cdot time =$ kw $\times (30 \times 24)h =$ kwh $=$ Mwh

3. Using appropriate diagram and equation, describe the basic operation of a proton exchange membrane (PEM) fuel cell. PEM

Basic Operation of Fuel Cells

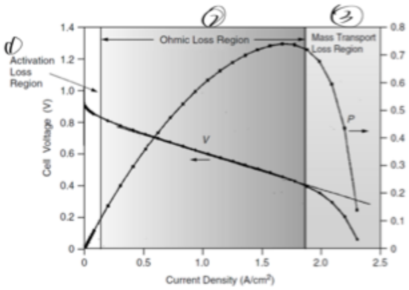


Basic Operation of Fuel Cells

- A single cell consists of two porous gas diffusion electrodes separated by an electrolyte.
- It is the choice of electrolyte that distinguishes one fuel cell type from another.
- The electrolyte consists of a thin membrane that is capable of conducting positive ions but not electrons or neutral gases.
- The entering hydrogen gas has a slight tendency to dissociate into protons and electrons as follows:
$$H_2 \leftrightarrow 2H^+ + 2e^-$$
- This dissociation can be encouraged by coating the electrodes or membrane with catalysts to help drive the reaction to the right.

4. Draw the typical electrical characteristics of a PEM fuel cell, clearly marking different operating regions. 电气特性.

Electrical Characteristics of Real Fuel Cells



5. Describe various types of losses in a Fuel cell which reduces its performance.

Losses in the Fuel Cell

- *Activation losses* result from the energy required by the catalysts to initiate the reactions. The relatively slow speed of reactions at the cathode, where oxygen combines with protons and electrons to form water, tends to limit fuel cell power.
- *Ohmic losses* result from current passing through the internal resistance posed by the electrolyte membrane, electrodes, and various interconnections in the cell.
- Another loss, referred to as *fuel crossover*, results from fuel passing through the electrolyte without releasing its electrons to the external circuit.
- And finally, *mass transport losses* result when hydrogen and oxygen gases have difficulty reaching the electrodes. This is especially true at the cathode if water is allowed to build up, clogging the catalyst.
- For these and other reasons, real fuel cells, in general, generate only about 60–70% of the theoretical maximum. 40% - 60%

* PEM
① used in HEVs
② highest available efficiencies 45%
③ 50W - 250kW

DMFC

6. What are the key advantages of Direct Methanol Fuel cell over PEM fuel cell?

Uses liquid methanol, which is easier to store and transport than hydrogen gas.
Suitable for portable devices like laptops and phones. CH_3OH instead of gaseous hydrogen.

7. Describe the key characteristics of Alkaline Fuel cell? AFC

Electrolyte: Potassium hydroxide (KOH).
Operates at 90–100 °C.
Highly efficient and reliable but sensitive to CO2, requiring pure oxygen.
and the charge carrier is OH^- rather than H^+ ions.
④ unlikely that these will be used in terrestrial applications

8. What are the key advantages of Fuel cell over fossil fuel based power plants? 燃料电池优点

- Fuel cells convert chemical energy contained in a fuel (hydrogen, natural gas, methanol, gasoline, etc.) directly into electrical power.
- Fuel-to-electric power efficiencies as high as 65% are likely, roughly twice as efficient as the average central thermal power stations.
- The usual combustion products (SOx, particulates, CO, and various unburned or partially burned hydrocarbons) are not emitted.
- They are inherently modular in nature, so that small amounts of generation capacity can be added as loads grow.

9. Describe Electrolysis of water for production of Hydrogen. 水的电解

- When an electrical current is forced through water added with an electrolyte, water molecules can be broken apart, releasing hydrogen and oxygen gases: $2H_2O \rightarrow 2H_2 + O_2$
- De-ionized water introduced into the oxygen side of the cell dissociates into protons, electrons, and oxygen.
- The oxygen is liberated, the protons pass through the membrane, and the electrons take the external path through the power source to reach the cathode where they reunite with protons to form hydrogen gas.

Process:
- Electricity splits water into hydrogen and oxygen.
- At the anode: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
- At the cathode: $4H^+ + 4e^- \rightarrow 2H_2$
- Overall: $2H_2O \rightarrow 2H_2 + O_2$

$A = P \times CRF(i, n)$

$CRF(i,n) = Capital\ recovery\ factor(yr^{-1}) = \frac{i(1+i)^n}{(1+i)^n - 1}$

$1\$ = 100¢$

10. A wind farm project has fifty (50) 2000-kW turbines with 80-m blades. Capital cost is \$100 million and the O&M cost for the first year is \$2 million. The O&M cost is escalating at the rate of 5% per year. The project will be financed with a \$100 million, 30-yr loan at 8% interest. Turbines are exposed to Rayleigh winds averaging 8.5 m/s. What is LCOE for the wind farm? $\rightarrow e$ $n=30$ $G = 10^9$

The ratio of the equivalent annual cost (\$/yr) to the annual electricity generated (kWh/year) is called the levelized cost of electricity (LCOE).

① $CF = 0.087\bar{V} - \frac{P_R(kW)}{[D(m)]^2} = 0.087 \times 8.5 - \frac{2000}{80^2} = 0.427$

② For 50 such turbines, the annual electrical production will be

Annual energy $= 50 \times 2000kW \times 8760\ h/yr \times 0.427 = 374 \times 10^6 kWh/yr$

③ The debt payments will be $(i = 9 = 0.08)$

$A = P \cdot \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] = 100,000,000 \times \left[\frac{0.08(1+0.08)^{30}}{(1+0.08)^{30}-1}\right] = \$8.8 \times 10^6/yr$

④ The levelized O&M cost is $= 2 \times 10^6 \times \left[\left(\frac{1.328}{0.1665}\right) \cdot \left(\frac{0.805}{9.0626}\right)\right] = 3.55 \times 10^6 \$$

O&M cost $= A_0 [PVF(d', n) \cdot CRF(d, n)] = 2 \times 10^6 \times \left[\left[\frac{(1+d')^n - 1}{d'(1+d')^n}\right] \cdot \left[\frac{d(1+d)^n}{(1+d)^n - 1}\right]\right]$

⑥ The levelized price at which electricity needs to be sold is

Selling price $= \frac{8.8 \times 10^6 \times 30 + 3.55 \times 10^6}{30 \times 374 \times 10^6 kWh/year} = 0.238 \$/kwh = 23.8 ¢/kwh$

NPV and IRR with Fuel Escalation

- The chances are that the cost of fuel in the future will be higher than it is today.
- Fuel price escalation factor (e) is used in the present worth analysis:

$$PVF(d,n) = \frac{1+e}{1+d} + \frac{(1+e)^2}{(1+d)^2} + \cdots + \frac{(1+e)^n}{(1+d)^n} = \frac{(1+d)^n - 1}{d(1+d)^n}$$

- The fuel price escalation can be captured through the equivalent discount rate.

$$\frac{1+e}{1+d} = \frac{1}{1+d'} \text{ where } d' = \frac{d-e}{1+e}$$

A 每年偿还金额

Annualizing the Investment 投资年化

- Extra capital required for an energy investment will be borrowed from a lending company.
- The extra capital cost is converted into a series of n equal annual payments (A) that eventually pay off the loan(P) with interest (i)

$$A = P \times CRF(i, n)$$

$$CRF(i,n) = Capital\ recovery\ factor(yr^{-1}) = \frac{i(1+i)^n}{(1+i)^n - 1}$$

$$CRF(i,n)\ per\ month = \frac{(i/12)[1+(i/12)]^{12n}}{[1+(i/12)]^{12n} - 1}$$

P - 贷款/借贷 本金

Levelized Costs

$P = A \cdot PVF(d, n)$

- The cost of a power plant has two key components - an up-front fixed cost to build the plant plus an assortment of costs that will be incurred in the future.
- In the usual approach to cost estimation, a present value calculation is first performed to find an equivalent initial cost, and then that amount is spread out into a uniform series of annual costs.
  - Levelized annual costs = $A_0[PVF(d', n) \cdot CRF(d, n)]$ 要记住
- The ratio of the equivalent annual cost (\$/yr) to the annual electricity generated (kWh/year) is called the levelized cost of electricity (LCOE).

Levelizing Factor 平准化成本.

$$\text{Levelizing factor (LF)} = \left[\frac{(1+d')^n - 1}{d'(1+d')^n}\right] \cdot \left[\frac{d(1+d)^n}{(1+d)^n - 1}\right]$$

MG Control

- MGs should be able to not only operate autonomously but also interact with the main grid.
- In the grid-connected operation mode, the MGs are integrated into a constantly varying electrical grid with changing tie-line flow, voltages, and frequency. To cope with those variations, to respond to grid disturbances, and to perform active power/frequency regulation, as well as reactive power/voltage regulation, MGs need to use proper control loops.
- Furthermore, suitable islanding detection feedbacks/algorithms are needed to ensure a smooth transition from the grid-connected to islanded mode to avoid cascaded failures.

Hierarchical Control Strategy

Consists of four levels:
1. local (primary) controls,
2. secondary controls,
3. central/emergency controls, and
4. global controls

Price of Electricity from a Wind Farm - Example

A wind farm project has 40 1500-kW turbines with 64-m blades. Capital costs are \$60 million and the levelized O&M cost is \$1.8 million/yr. The project will be financed with a \$45 million, 20-yr loan at 7% plus an equity investment of \$15 million that needs a 15% return. Turbines are exposed to Rayleigh winds averaging 8.5 m/s.

What levelized price would the electricity have to sell for to make the project viable?

Solution

$$CF = 0.087\bar{V}\ (m/s) - \frac{P_R(kW)}{[D(m)]^2} = 0.087 \times 8.5 - \frac{1500}{64^2} = 0.373$$

For 40 such turbines, the annual electrical production will be

$$\text{Annual energy} = 40 \text{ turbines} \times 1500 \text{ kW} \times 8760 \text{ h/yr} \times 0.373 = 196 \times 10^6 \text{ kWh/yr}$$

The debt payments will be

$$A = P \cdot \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] = \$45,000,000 \cdot \left[\frac{0.07(1+0.07)^{20}}{(1+0.07)^{20} - 1}\right] = \$4.24 \times 10^6/yr$$

The annual return on equity needs to be

$$\text{Equity} = 0.15/yr \times \$15,000,000 = \$2.25 \times 10^6/yr$$

The levelized O&M cost is \$1.8 million, so the total for O&M, debt, and equity is

$$\text{Annual cost} = \$(4.24 + 2.25 + 1.8) \times 10^6 = \$8.29 \times 10^6/yr$$

The levelized price at which electricity needs to be sold is therefore

$$\text{Selling price} = \frac{\$8.29 \times 10^6/yr}{196 \times 10^6 \text{ kWh/yr}} = \$0.0423 = 4.23¢/kWh$$

11. A photovoltaic system that generates 8000 kWh/yr costs $15,000. It is paid for with a 6%, 20-year loan.

$L=15000$ $r=0.06$ $n=20$

平准化度电成本 LCOE

a) Ignoring any tax implications, what is the cost of electricity from the PV system?

b) With local utility electricity costing 11¢/kWh, at what rate would that price have to escalate over the 20-year period in order for the levelized cost of utility electricity be the same as the cost of electricity from the PV system?

a) $P = \frac{L \cdot r \cdot (1+r)^n}{(1+r)^n - 1} = \$1307.3/yr$

the cost of electricity:

$$\text{LCOE} = \frac{\text{Annual Loan Payment}}{\text{Annual Electricity Generation}}$$

$$\text{LCOE} = \frac{1,307.3}{8000} = 0.1634\,\$/\text{kWh} = 16.34¢/kWh$$

b) $P_{final} = P_{initial} \cdot (1+g)^n$

$16.34 = 11 \cdot (1+g)^{20}$

$g \approx 2.01\%$

The utility price must escalate at 2.01% per year.

12. A small business uses 100 kW of power and 24,000 kWh/month during peak period. It uses 20 kW peak power and 10,000 kWh/month during off-peak period. Calculate its monthly electricity bill if:

a) Time of Use (TOU) rate schedule is used
On-peak : 12¢/kWh and Off-peak 7¢/kWh

只适合看有最大的峰值 在时间最大

b) Demand Charge Schedule is used with
Energy charge 6¢/kWh and demand charge of $9/mo-kW.

a) peak cost = 24000 × 0.12 = 2880 $ off-peak cost = 10000 × 0.07 = 700 $

Total bill = 2880 + 700 = 3580$

b) Energy cost = (24000 + 10000) × 0.06 = 2040$

Demand cost = (100 + ~~20~~) × 9 = 900 $ Total =

13. A commercial customer uses demand charge schedule and consumes 20,000 kWh power month with a peak demand charge of 100kW. The rate schedule used is energy charge 6¢/kWh and demand charge of $9/mo-kW. A sales engineer proposes to install an equipment that would reduce the peak demand to 80kW and increase energy efficiency by 10%. What should be cost of the equipment if the pay-back period is less than 3 years?

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

成本回收期 [illegible] mon/年

① Energy reduction → Energy savings: 20000 × 0.1 = 2000 kWh/mo

Energy cost savings: 2000 × 0.06 = 120 $/mo

② Demand reduction → Demand savings: (100 − 80) × 9 = 180$/mo

③ Total savings: (120 + 180) × 12 = 3600$/year

④ cost = 3600 × 3 = 10800$

14. Two customers use 10,000kWh per month and pay according to a demand charge schedule with energy charge 6¢/kWh and demand charge of $9/mo-kW. One customer has a load factor of 15% whereas the other has a load factor of 60%. What is difference in their monthly energy bills?

They both have the same energy costs:

10000 kWh/mo × 0.06/kWh = $600/mo

$$\textit{Load factor } (\%) = \frac{\textit{Average Power}}{\textit{Peak Power}} \times 100\%$$

$$\text{Peak}(A) = \frac{10000\ \text{kWh/mo}}{15\% \times 24\text{h/day} \times 30\ \text{day/mo}} \times 100\% = 92.59\ \text{kW}$$

which, at $9/mo-kW, will incur demand charges of $833.31/mo

Bill(A) = (10000 × 0.06) + (92.6 × 9) = 1433.4$

$$\text{Peak}(B) = \frac{10000\ \text{kWh/mo}}{60\% \times 24\text{h/day} \times 30\ \text{day/mo}} \times 100\% = 23.15\ \text{kW}$$

costing $208.35/mo

Bill(B) = (10000 × 0.06) + (23.1 × 9) = 807.9$

Example 5.7 Net Present Value of Premium Motor with Fuel Escalation. The premium motor in Example 5.6 costs an extra $500 and saves $192/yr at today's price of electricity. If electricity rises at an annual rate of 5%, find the net present value of the premium motor if the best alternative investment earns 10%.

e d

Solution. Using (5.15), the equivalent discount rate with fuel escalation is

求现值

$$d' = \frac{d-e}{1+e} = \frac{0.10 - 0.05}{1 + 0.05} = 0.04762$$

From (5.9), the present value function for 20 years of escalating savings is

n=

$$\text{PVF}(d', n) = \frac{(1+d')^n - 1}{d'(1+d')^n} = \frac{(1+04762)^{20} - 1}{0.04762(1+0.04762)^{20}} = 12.717\ \text{yr}$$

From (5.10), the net present value is

$$\text{NPV} = \Delta A \times \text{PVF}(d', n) - \Delta P = \$192/\text{yr} \times 12.717\ \text{yr} - \$500 = \$1942$$

(Without fuel escalation, the net present value of the premium motor was only $1135.)

What is a Microgrid?

- Micro grids comprise LV distribution systems with distributed energy resources (DER) together with storage devices (flywheels, energy capacitors and batteries) and flexible loads.
- Such systems can be operated in a non-autonomous way, if interconnected to the grid, or in an autonomous way, if disconnected from the main grid.
- The operation of micro sources in the network can provide distinct benefits to the overall system performance, if managed and coordinated efficiently.
- Microgrid is an integration platform for supply-side (microgeneration), storage units and demand resources (controllable loads) located in a local distribution grid.
- A microgrid should be capable of handling both normal state (grid-connected) and emergency state (islanded) operation.

Importance of Storage System

During renewable excess/deficit

In grid connected mode batteries can store excess of renewable energy when demand is less and supply the required deficit power when renewable generation is less

During Islanded mode

Grid support action: Helps to regulate the grid voltage by its charging/discharging action.

To flatten load curve

Since both renewable generation and loads are variable by nature, usage of batteries can flatten the load curve.

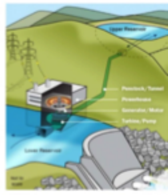
Performance factors for energy storage systems

- Energy capture rate and efficiency
- Discharge rate and efficiency
- Dispatchability and load following characteristics
- Scale flexibility
- Durability – cycle lifetime
- Mass and volume requirements – footprint of both weight and volume
- Safety – risks of fire, explosion, toxicity
- Ease of materials recycling and recovery

Pumped Hydro System（抽水蓄能）

Pumped Hydro System

- Water is pumped from a lower reservoir uphill and then allowing it to flow downhill to through turbines to produce electricity.
- Readily available and widely used in high power applications
- Lower cost of power, frequency regulation on the grid, and reserve capability
- Can only be implemented in areas with hills .



Flywheels（飞轮储能）

A cylinder that spins at a very high speed, storing kinetic energy.

Advantages of Flywheels

- Charge and discharge rapidly
- Affected little by temperature fluctuations
- Take up relatively little space
- Long life span
- Tolerant of abuse
- Lower maintenance requirements than batteries
- Flywheels with magnetic bearings and high vacuum can maintain 97% mechanical efficiency, and 85% round-trip efficiency
- Flywheels may be used to store energy generated by wind turbines during off-peak periods or during high wind speeds.

- Disadvantage: Power loss faster than batteries.

Compressed Air Energy Storage (CAES) 压缩空气储能

Compressed Air Energy Storage (CAES)

- Utilities use electricity generated during off-peak hours (i.e., storage hours) to compress air and store it in airtight underground caverns.
- When the air is released from storage, it expands through a combustion turbine to create electricity.
- Conserves some natural gas by using low-cost, heated compressed air to power turbines and create off-peak electricity.
- Has low efficiency due to the extra reheating energy needed to turn on the turbines.
- For every kWh of energy going in, only 0.5 kWh of energy can be taken out.

电池

Batteries

Lead Acid Batteries
- Suitable for large storage application
- Low cost but high maintenance

Sodium Sulphur (NaS)
- High energy density (Four times of lead acid),
- Long cycle capability
- Suitable for stationary energy storage applications

Lithium-Ion
- Environmental friendly
- Suitable for portable devices like mobile phones, laptops, power tools and also in Electric vehicles

Lithium-Ion Polymer
- Higher specific energy than other lithium battery types and are being used in applications where weight is a critical feature
- Suitable for portable devices like mobile phones and notebook computers

DC Microgrid

Importance of DC

- Various conversion stages like AC-DC/DC-AC can be avoided by forming DC Grid and Overall System efficiency can be improved.
- No problem of reactive power, harmonics, frequency control.
- No synchronization issues and Controlling becomes easier.
- Eddy current, hysteresis losses and skin effect are absent.
- Reduces stress on conventionally grid, congestion of transmission line will be reduced.

DC operation based on Voltage Level

HVDC
- Operating voltage range 500kV and above, Economical and efficient over AC at long distance transmission.
- Power transfer between two separate AC networks.

MVDC
- Operating voltage level is 11kV and 33kV
- Can provide controlled power transfer between two 11kV and 33kV networks for better utilization of existing network.

LVDC
- Operating voltage levels are 48V/380V/600V
- Reduces dependency on main grid, reliability to the consumer can be improved, and provide supply to remote villages.

Single-bus DC Microgrid

Simple, suitable for low-voltage DC systems

Direct storage: low cost, poor controllability

Converter-interfaced storage: flexible control, higher reliability

Multi-bus DC Microgrid

Multiple buses improve efficiency and flexibility

Dual-bus reduces single-point failure

Microgrid clustering enables energy sharing

SST enables intelligent low-voltage energy management

Reconfigurable DC Microgrid

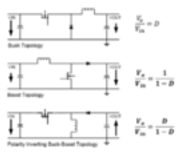
Topology can be reconfigured

Ring bus provides redundancy

Zonal structure enables fault isolation

Multi-terminal DC offers multiple power paths

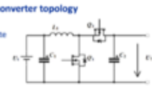
Buck, Boost, Buck-Boost Converters



Bi-Directional DC-DC converters

The key constraints of bidirectional DC-DC converter are:
- Single converter
- Simplicity using minimal storage elements.
- Allow bi-directional power flow from one source to other and vice versa.

Non-isolated bi-directional converter topology
- Half-bridge converter
- Cascaded half-bridge converte



Protection Devices in LVDC（常见的直流保护器件）

Fuses/LV power CBs/Moulded Case Circuit

Brèakers/Isolated case CBs

Challenges in DC Microgrid

- Lack of Standards
- Protection issues : no DC circuit breaker
- Lack of DC infrastructure
- Circulating currents in parallel operation, Grounding issues.
- Unable to feed AC loads of Industries, Commercial and Residential applications.

Example 5.4 Impact of Ratcheted Demand Charges on an Efficiency Project. A customer's highest demand for power comes in August when it reaches 100 kW. The peak in every other month is less than 70 kW. A proposal to dim the lights for 3 h during each of the 22 workdays in August will reduce the August peak by 10 kW. The utility's energy charge is 8¢/kWh and its demand charge is $9/kW-mo with an 80% ratchet on the demand charges.

棘轮

a. What is the current annual cost due to demand charges?
b. What annual savings in demand and energy charges will result from dimming the lights?
c. What is the equivalent savings expressed in ¢/kWh?

Solution

a. At $9/kW-mo, the current demand charge in August will be

$$\text{August} = 100\ \text{kW} \times \$9/\text{kW-mo} = \$900$$

For the other 11 months, the minimum demand charge will be based on 80 kW, which is higher than the actual demand:

$$\text{Sept–July demand charge} = 0.8 \times 100\ \text{kW} \times \$9/\text{kW-mo} \times 11\ \text{mo} = \$7920$$

So the total annual demand charge will be

$$\text{Annual} = \$900 + \$7920 = \$8820$$

b. By reducing the August demand by 10 kW, the annual demand charges will now be

$$\text{August} = 90\ \text{kW} \times \$9/\text{kW-mo} = \$810$$
$$\text{Sept–July} = 0.8 \times 90\ \text{kW} \times \$9/\text{kW-mo} \times 11\ \text{mo} = \$7128$$
$$\text{Total annual demand charge} = \$810 + \$7128 = \$7938$$
$$\text{Annual demand savings} = \$8820 - \$7938 = \$882$$

7

e.g. The demand charge for every month may be based on 80% of the annual peak demand.

$$\text{August energy savings} = 3\ \text{h/d} \times 10\ \text{kW} \times 22\ \text{days} \times \$0.08/\text{kWh} = \$52.80$$

$$\text{Total Annual Savings} = \$882 + \$52.80 = \$934.80$$

Notice that the demand savings is 94.4% of the total savings!

c. Dimming the lights saved 3 h/d × 10 kW × 22 d = 660 kWh and $934.80, which on a per kWh basis is

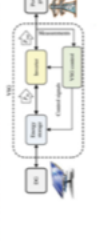
$$\text{Savings} = \frac{\$934.80}{660\ \text{kWh}} = \$1.42/\text{kWh}$$

In other words, the business saves $1.42 for each kWh that it saves, which is about 18 times more than would be expected if just the $0.08/kWh cost of energy is con

“解决低惯量”的关键方案

Virtual Synchronous Generators : Dynamic Performance and Characteristics

- A solution towards stabilizing a grid/MG with numerous low-inertia DGs is to fortify the system with additional inertia, virtually.
- Virtual inertia can be established by using short-term energy storage together with a power electronics inverter/converter and a proper control mechanism in a system that is called virtual synchronous generator(VSG).



Microgrid Protection

- Protection of Microgrid especially when it is islanded is quite challenging
- The first and foremost challenge is to detect the islanding of the microgrid
- The second important challenge is how to provide segments of the microgrid with sufficient coordinated fault protection while operating as an island separated from the utility