Power System Generation, Transmission and Distribution

UNIVERSITY OF ENERGY AND NATURAL RESOURCES

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

LECTURER

AWAAFO AUGUSTINE

Introduction to Power Generation, Transmission and Distribution

In this lecture, students will be introduced to the perspective of power generation, transmission, and distribution.

- All of you know that electric energy is an essential ingredient for everything in today’s world of advancement and technology. Whatever you do, from morning to evening, you practically consume electric energy. Be it charging your phone, heating water for making your tea, or taking a bath.
- So, then we need to generate electric energy.
- After generation, you have to transmit it also, because as you know, the load may not be close to the generating station.
- You have to transmit your power economically, because, in anything whatever you may say, cost remains a main factor in any activity.
- Power is mostly transmitted over long distances except with **distributed generation.**
- After transmitting your power, it can then be distributed to your load centers or consumers.

Introduction to Power Generation, Transmission and Distribution

- The per capita energy consumption is a very reliable indicator of any country how much progress it has done.
- There are other indicators, For example, how many people own telephones? How many people own cars? How many people have the houses of their own?
- Now, how do you say the per capita energy consumption is a reliable indicator; if we had no activity, if we had no industry, we do not need electric energy.
- This does not imply wasting energy. Energy conservation, sustainability, and energy efficiency are very important considerations in the consumption of energy.
- Obsolete technology has to be discarded.
- The developed world is already consuming so much energy while the developing world is consuming less energy
- So, the developed world has to reduce energy consumption, and the developing world has

to increase.

Conventional and non-conventional sources of energy conversion

conventional sources: These are the non-renewable sources of energy that already have high penetration generation mix. They include;

- Fossil fuels: That is coal, oil, and natural gas, which are the three main fuels, that can be burnt to produce heat energy, which can, later be converted into mechanical energy and subsequently electric energy.
- Hydrogeneration
- Nuclear

Non-conventional sources: These are renewable sources of energy, and they have low penetration generation mix. They include;

- Solar
- Wind
- Biomass
- Tidal energy, etc.

Conventional and non-conventional sources of energy conversion

We have to intensify the efforts to develop alternate sources of energy. Why because, we have to slowly, but surely replace the need for conventional power generation, with nonconventional sources. Why? Because

- They are sustainable
- They are less polluting
- They are perennial sources. Nobody can charge you for

getting sunlight in your house.

- Solar, tidal, wind, biomass, geothermal, and so on must be the way to go.
- We must reduce pollution because it affects everybody, not only human beings, it affects vegetation, it affects buildings, etc.
- Anti-pollution technologies like carbon capture, and carbon sequestration are necessary.
- Bulk power generating stations are easy to control pollution because centralized one-point measures can be adopted, it is very easy. When people are in groups it is easy to control. If all of you are standing in different places,different corners, it is not easy to monitor.

Conventional and non-conventional sources of energy conversion

- Another important issue is that, when power is generated it must be consumed or stored.
- Power storage systems like compressed air storage, hydrogen fuels, pump storage plants, etc.
- These are not so popular in practice since most of them are not so economical so you have to generate power when you need it.
- Therefore load forecasting or planning is important before power generation.
- You have to constantly estimate, and forecast load. So, load forecasting has become a very important topic in power systems, and electric energy systems. Even in renewable energy, you have to forecast, how much wind power can be consumed, and how much solar energy can be used, because consumer loads vary randomly and if there are no users, why produce power?
- To efficiently generate power to satisfy the customer and also reduce cost, the customer load factor must be close to unity.

$Load\ factor\ = \frac{Avg\ load}{Peak\ load}$ avg load= Actual consumption of a customer on a normal day

Peak load = The maximum consumption of consumption at a particular time = Maximum plant generation

Conventional and non-conventional sources of energy conversion

- Another important factor is the diversity factor.

What is diversity?

- In your house, you do not keep all the bulbs, all the fans, all the AC, and all the coolers on all the time, but you do have them. In case you shift from the dining room to bedroom, bedroom to drawing room, drawing room to study room, you go and start that particular bulb, particular fan, and so on.
- So, the summation of individual maximum demands, upon maximum load on the system is always more than one, because you are not going to have all maximum demand all the time.
- At a given point in time, the maximum load on the system will be much less, maybe only two tube lights are on, and maybe only two fans are on. You may have ten fans, even in your classroom, there may be four fans, but if it is an empty class; only the first two fans are on where you are sitting in the first two tables, or benches, or chairs and tables. Why should you keep those fans on which are not going to serve any purpose, it will be a waste of energy, which you cannot afford.
- $Diversity\ factor = \dfrac{sum\ of\ all\ loads\ connected\ to\ power\ source}{sum\ of\ loads\ consumer\ power\ at\ a\ particular\ time}$

- A higher diversity factor is better because it means you are not wasting power.

Conventional and non-conventional sources of energy conversion

- Power must also be transmitted at high voltage to reduce losses. This is because power is a function of voltage and current, therefore transmitting at high voltage implies less current which will reduce the I^2R losses.

For example, if A 20 kV generator is expected to deliver 2000 MVA power to a load, 100km away. Let's assume the effective resistance of the line is 0.003 Ω/km.Let's look at two scenarios:

- the generator is connected directly to the transmission line.
- the generator is connected to the transmission line, via a 1:10 step-up transformer. At the load center, a step-down transformer is used to bring the voltage to the appropriate level.

- Transmission voltage may be as high as 765 kV;
- Typical transmission voltage levels are 110, 220, 400, 750 kV for Continental Europe, 132, 275, 400 kV for the United Kingdom and 115, 230, 345, 500, 765 kV for the United States
- In Ghana, transmission voltages are 161 kV, and 330 kV and it is operated by Gridco.

Conventional and non-conventional sources of energy conversion

- Power must also be transmitted at high voltage to reduce losses. This is because power is a function of voltage and current, therefore transmitting at high voltage implies less current which will reduce the I^2R losses.

For example, if A 20 kV generator is expected to deliver 2000 MVA power to a load, 100km away. Let's assume the effective resistance of the line is 0.003 Ω/km.Let's look at two scenarios:

Case I: the generator is connected directly to the transmission line.

Case II: the generator is connected to the transmission line, via a 1:10 step-up transformer. At the load center, a step-down transformer is used to bring the voltage to the appropriate level.

Conventional and non-conventional sources of energy conversion

Case I:
Transmission voltage: 20 kV
Line current:

$$I_L = \frac{2000 \times 10^6}{\sqrt{3} \times 20 \times 10^3} = 57.74kA.$$

Transmission loss:

$$(57.74 \times 10^3)^2 \times 0.3 = 1000MW$$

Thus the transmission loss is 50%.

Conventional and non-conventional sources of energy conversion

Case II:

Transmission voltage is $10 \times 20kV = 200kV$

Line current:

$$I_L = \frac{2000 \times 10^6}{\sqrt{3} \times 200 \times 10^3} = 5.774kA.$$

Transmission loss:

$$(5.774 \times 10^3)^2 \times 0.3 = 10MW$$

Thus the transmission loss is 0.5%.

Conventional and non-conventional sources of energy conversion

- Power factor is another important consideration.

$$PF(\cos\theta) = \frac{Active\ power\ (P)}{Apparent\ power\ (IV)}, \qquad \mathrm{P} = \mathrm{IV}\cos\theta$$

You should have an incentive to have a better power factor, because If the power factor is low,

The P is equal $\mathrm{IV}\cos\theta$ and voltage being constant, the current will go up to get the same value of P.

- Current going up is not good, it is bad because there will be more more losses ($I^2R\ losesse$)
- Your conductor will get heat up and your insulation may melt.
- So, our aim should be to have as much higher power factor as possible
- If power factor is high we say power quality is good

Conventional and non-conventional sources of energy conversion

The plant capacity factor is another important consideration: This is the ratio of actual energy produced to the maximum possible energy that could have been produced.

$$Plant\ capacity\ factor = \frac{Actual\ energy\ produced}{Max.energy\ that\ plant\ can\ produce} = \frac{Avg\ demand}{installed\ capacity}$$

- If you have a better plant capacity factor it means you are using the plant optimally. You don’t have to buy a 20kW generator when your load is just 10kW.

Plant use factor; The Plant use factor is nothing but, actual energy produced in kilowatt hours upon plant capacity into time the plant has been in operation.

$$Plant\ use\ factor = \frac{Actual\ energy\ produced\ \ in\ kWh}{Plant\ capacity\ (kW) \times Plant\ operation\ time\ (hrs)}$$