4M18 CRIB 2018

Q1 (a) (i) Frequency control (i.e. Feedback of frequency) is used at fast time scales. The supply is adjusted based on deviations in frequency as excess supply will increase the frequency and excess demand will decrease it, working with the mechanical inertia.

(ii) Optimal Power Flow is used at slower time scales. This is an optimisation problem that determines the power allocation within the network so as to minimise generation cost and also satisfy the various operational constraints.

(b) A main challenge is associated with the fact that large gains in the feedback policy could destabilise the system, whereas a low gain leads to a conservative design with a slow response. The problem becomes more complicated in a network, as the generators interact with one another due to the power transfers between them, with the transient behaviour of each generator acting as a disturbance to other generators. [2 marks]

(ii) Optimal Power Flow is used at slower time scales. This is an optimisation problem that determines the power allocation within the network so as to minimise generation cost and also satisfy the various operational constraints related to the grid, such as losses and backup.

Relative to frequency control it additionally incorporates economic efficiency and system constraints into consideration. A main challenge in its implementation is the computation complexity of the problem as it is generally non convex and involves a very large number of variables and parameters. This is further complicated by the intermittent renewables.
[3 marks]

(b) ‘Smart grid’ ways to facilitate the balancing of supply and demand include:

1. Demand side management via real time pricing. The electricity prices are made visible to consumers so that they are incentivised to adjust their demand.
2. Smart loads/appliances responding to deviations in frequency
3. Transmission and Distribution data (measurements in realtime)

Challenges (any two): Highly distributed ‘control’ schemes can lead to instabilities if not properly designed. Cost of various systems added to the grid. Public willingness to adopt these smart appliances. Loss of efficiency. Demand side on pricing may lead to herd behaviour and unstable large swings in demand. [5 marks]

Few mentioned the grid infrastructure. Storage in EV’s was seen as a good answer, but grid scale storage other than in EV’s remains difficult due to insufficient scale, inefficiency, cost.

(c). (i) Interconnectors offer access to other countries and grids, so provide a greater diversity of potential suppliers, offering energy at differing times and more redundancy. e.g. French nuclear. Offer an economic market place for trading energy, facilitating competition in the European market hopefully lowering costs e.g. Buy excess wind power from Holland. Finally increased interconnection can also help with intermittence issues posed by renewable generation (mainly wind), better integration of renewables allows more percentage of energy from renewables. [3 marks]

(ii) IGBT converters provide: P and Q on demand; a fast response increasing stability; Good AC waveforms. In other words they can support a weak grid; they can be used to start up a collapsed ac grid. [3 marks]

(iii) Features are for example >40 km undersea, which can only be done with HVDC, further distances on land are also easy to accommodate to connect to the dc/ac converter at a convenient grid location; short ac sections may also be needed to connect to a good part of the high voltage ac grid. Can use a converter on Aldernay as a concentrator for wind power.
[4 marks]

Part c was generally well done although few could account for IGBT converters - missing the lecture material showing how IGBT converters synthesise excellent sine waves!

Q2. (a) Systems question on the basis that steel production requires high grade heat produced by coal and developing economies require steel. Concrete also requires huge amounts of energy at a high temperature not easily created by electricity. The 'electrical' side of it is that coal is easy to transport and use in power stations near cities in countries that have no electrical or gas transmission grid infrastructure.

To industrialise without coal and no grid infrastructure would be very difficult as it would mean trying to leep frog the development process. In some things such as telephone networks this is possible, and renewable energy with local generation and small area networks would also work. This would probably necessitate some kind of energy storage and local 'smart' appliances. But steel and concrete needed for building a city would need to be produced locally in some form. Maybe recycled steel beams from post industrial countries could be used to reduce the energy in steel, or recycled using electric arc furnaces. Using standardised concrete blocks for building rather than reinforced poured concrete as cement requires a high energy input. Possibly use locally made bolts to bolt concrete blocks together. Lightweight steel could be formed in the developing country into computer analysed shapes which have high rigidity to leep frog heavy construction and processing. [8 marks]

Few spotted the need for steel and concrete. Many assumed gas was easy to adopt by developing countries ignoring the infrastructure needed and also minimising the need for electricity.

(b) (i) There is a correlation between EPC rating and type of home heating. Clearly electric heating is inefficient in terms of heat delivered to a dwelling, as >50% of the heat energy is lost, assuming that gas is the original fuel. There is also the factor that the older homes with electric heating may be poorly insulated. Top up electric heating is also expensive [3 marks]

(ii) Wind power is random and not so good for direct use, but is ideal for heat based ‘smart’ storage heaters if the control of the storage heater is passed to the smart grid. In this case electricity may be very cheap and renewable based. A dense electricity distribution grid would be necessary. However if the wind is not blowing then the city may need to use direct electric heating which is expensive to produce and deliver and inefficient. Clearly comfort levels may be moderated if a smart meter showing instant pricing were in place in which case a choice may be made to reduce comfort. For easier heat storage, it would be better to have a large storage facility, using something like water and then actually use hot water distributed for heating. Better insulation is necessary. [6 marks]

(iii) Rural distribution of electricity is at 33 kV and the line losses for an additional heating load would be high. Smart grid techniques would be the same, but CHP could be used in one area, perhaps for a factory (Wissingham) and then the electricity generated used in nearby villages or small towns so keeping the distances short. Similarly the wind and solar power need to be local, and digesters are attractive. Nice open fires needed for backup on very cold evenings! [3 marks]

Parts i and ii well done, but confusion in part iii over CHP in rural areas delivering heat to homes rather than heat to processes and electricity to homes.

Q3. (a) The cost of a new coal fired station is high compared to Gas and with a large amount of wind and solar energy any new plant is only needed perhaps early in the working day then early evening. With the recent cold period, large amounts of gas were 'reserved' for heating, so coal became the preferred energy source as it is easy to store in large quantities for the odd cold period. However, coal is probably more expensive after shipping than the gas, with new shale gas supplies coming on stream. Gaining planning permission would be hard with people not wanting piles of coal and tall chimneys locally. Gas may be stored in clean looking tanks, but these are expensive compared to piling up coal. Coal also has some nasty emissions beyond those of CO2. Also, the number of sites with the possibilities for CCS is small at present, as used oil wells are the most likely repositories. CCS also has an energy cost of around 10% (25% at the output) and CCS also requires a huge investment. Coal with CCS is less flexible than GT, requiring some generation to maintain the temperatures of the boilers (but reasonably controllable and can use biomass). Note the Coal fired stations were fired up fully at night ready for the day. Coal fired stations contribute to spinning reserve as do GTs. Although coal reserves are very extensive, gas is low CO2 and government policy is to adopt the easiest and quickest route to a low CO2 future. [10 marks]

Generally good answers, but few recognised gas is hard to store and might be needed for heating.

(b) List:

40 year life so long term forecasting planning is needed;
Fault clearing calculations;
Cost of equipment;
Losses (fixed and variable).

Rapid changes such as massively increased Solar Power in the UK in the distribution grid. Too large a transformer creates too much fixed loss and therefore costs a lot to buy and run. It may also increase the fault current so requiring more expensive breakers. Increased renewables may reduce the need for grid infrastructure. [6 marks]

By not 'listing', technical issues were missed by many.

(c) Scenarios are *not* predicting the future. They look at various versions of the possible future and see what definitely needs to be done, based on all or most scenarios and then what can be done cost effectively with minimal investment, then de risking by putting some plans in place. If the economy is doing well governments have fewer problems with putting laws in place to regulate behaviour and there is more money available for improvements to the system. Individuals may also have considerable spending power by acting en masse for example a rapid up take of EV's. Or they may create a rapid swing to energy providers that offer renewable energy only! Government may decide to build a nuclear plant which would also influence the grid structure. Overriding local planning permission restrictions for solar and CHP may increase the load on the local distribution system. [4 marks]

Despite having National Grid and Shell giving talks, there was a lot of confusion on show around scenario planning.

Q4. (a) Using an auction means the lowest price. This is an extremely low price, but follows the trend worldwide as wind has become a mature technology. Wind power is variable and peaks at any time and offers no grid support. This is difficult for the grid as there has to be some back up supply, and grid support (maybe capacitors) tending to make the grid 'system' expensive, thereby reducing the value of the wind energy. Solar in contrast is during the day and therefore more useful, and of more value. Thus Wind power is a source of cheap raw energy often not near to cities and there will be additional grid costs of making the energy accessible. Interconnectors are useful as any excess energy can be sold internationally if not needed. Good financial instruments may make its value easier to determine. [8 marks]

Most missed the idea that wind power is now a mature technology and the question asked specifically about wind farms.

(b) Clearly the solar power in the UK is in the distribution grid, which is great for EVs outside of cities, especially if smart charging at work is possible to use the mid day solar. The wind power is a problem as it will go into transmission. EV charging in cities may be a problem too. The transmission grid was built in the days of shifting bulk power to cities. This maybe fine as there are many cars are in cities too, but the city miles may be lower than the rural town miles. To make use of the wind power the grid may need to be much more grid like. That is also true with respect to fast charging on motorways. Some kind of grid may need to match the major road structure. The wind in Scotland is very good, but the distances to cities are very high so the advantages in generation are outweighed by the transmission losses. With wind farms in the SE and population in the SE we may need more transmission grid in the SE. EV's may be the salvation of the grid, since the solar generation is in the distribution grid and EV's charge from the distribution grid, so there is a reduced need for large power stations and bulk shifting of power. This trend can also be seen in the large number of interconnectors, coming in at close to population areas. The may also be a need to retain the transmission grid and the large capacity of CCGTs for their traditional use of stabilising the network, adding inertia and fault tolerance and back up. [12 marks]

Based on the National Grid guest lecture. Most seemed to understand that UK Solar is distribution grid connected and that EVs are charged from the distribution grid, but few put the two together. Quite a few missed the location of the Wind power mentioned.

Dr Patrick R Palmer, June 2018