IESIS
A MULTI-DISCIPLINARY ENGINEERING INSTITUTION

16 Robertson Street
Glasgow G2 8DS
Tel: 0141 248 3721
secretary@iesis.org www.iesis.org

Engineering Planning of the Electricity System

Part 1 Basic message

The Government strategy to reduce CO_2 emissions in electricity generation is that electricity generated from coal and gas fired generators will be replaced by that from renewable energy sources. As a result, power companies can make profits on subsidised renewable energy but struggle to make profits on coal and gas generators.

That seems to be a good outcome but there is a serious fault in the strategy. Closing down coal and gas generators without replacement (as is happening) results in increased risk to system security. Such risks include that demand will not be met (security of supply) and that the system may become unstable (security of operation). Risks of this kind are not controlled by market signals. They can only be controlled by planning based on engineering methodology. Such planning requires that a system approach be adopted where, for example, the effect on the system of changes to a part of the system are evaluated. Studies are now being undertaken to assess issues of this type but they are being carried out after decisions have been made.

We assert that, in order that the inherent risks in developing the Electricity System are kept to an acceptable level and hence that the system will be fit for purpose, what might be called a National Electricity Commission needs to be established that would have the following attributes:

1. All must work to a common goal of seeking to find ways to develop the Electricity System such that all risks are adequately controlled.
2. It must adopt a systems approach whereby all relevant issues are addressed and all consequences of introducing changes to the System are assessed.
3. The most advanced technologies should be applied in the drive to achieve the goals for the System.
4. The staff of the Commission must have the necessary range of high level competence - particularly technical competence and especially competence in power system engineering. The staff should be, as far as is practical, be free from political and commercial constraints. Where expertise is not available within the organisation, it should be procured from other sources.
5. The Commission should be required to draw up long term and short term plans for the System.
6. The operation of the Commission should, with the exception of issues that relate to national security, be transparent to the public. Data should be made available so as that members of the public can carry out studies independently of the Commission. Such contributions should be welcomed as having potential to help to achieve the system

goals.   Public consultations should be held about proposals before decisions have been made.

7. The Commission should be responsible for security of the system. The line of responsibility should be clearly defined.
8. The Commission must have authority to ensure that plans are implemented. Reference (1) describes an arrangement whereby this can be achieved.
9. The Commission should operate under an audited Quality Management system to seek to ensure that the objectives are being competently addressed.

It is noted that the 1926 Electricity Supply Act created a very successful structure similar to that suggested here (see Section 5.1).

Part 2 Background

1. Purpose

The purpose of this document is to express the principle that in order for the Electricity System to be fit for purpose, it is essential that a body be established that will apply engineering methodology to its development. Part 1 is a summary that includes a list of the essential attributes of the body. Part 2 provides background information.

2. Introduction

The electricity system is being squeezed by a pincer grip from two basic principles.
One arm of the pincer is a 'Market Principle' that market forces will deliver an electricity system that will be superior to one that has been subject to engineering planning.
The other arm is a 'Renewables Principle' that significant reductions in CO_2 emissions can be achieved by replacing thermal energy generation with generation from renewable sources .
In this document we examine these principles and make a recommendation as to what needs to be done about them.

3. The Market Principle

Arguments that are made to support this principle include:

- The success rate of central planning by government is low.
- The transfer of air travel to the private sector in the 1980s, for example, resulted in a range of quality of service and price that makes it affordable to a wide sector of the population. This is the type of result that can be expected from a free market electricity system.
- The present electricity system has deep problems with cost and security due to government intervention in the market. Government planning is the problem not the solution.

Counter arguments to the Market Principle include:

- There is no market mechanism that will reliably maintain the risk to security of supply (i.e. that the risk that demand will not be met) at a level that will be acceptable to customers.
- Nor is there a market mechanism that will reliably maintain the risk to security of operation of the system. Problems with voltage instability, reduced system inertia, reduced system damping, etc. require generators and other equipment to be of the right types and in the right places across the country - see section 6.2.
- Since low carbon electricity production is not cost competitive with thermal generation, the market will not deliver it.
- The historical record shows that tight regulation of the electricity system can be highly successful - see Section 5.

Our conclusion: The fundamental difficulty is that although costs to consumers might be favourable in a free market, the market arrangements will not provide adequate levels of security or emissions reduction.

We are being reassured by DECC and National Grid that, despite the continuing closure of thermal generators, the system remains secure in relation to supply because of measures that can be taken when difficulties arise. With almost no projects underway to replace thermal generators it is difficult to believe that this risk to security is not increasing.

The drive to reduce emissions is approaching a situation where there will be no price competition for any of the main generating methods. Renewable energy is subsidised, new nuclear has price guarantees and coal and gas will soon also need price guarantees since they are fast becoming uneconomic for the providers.

The inescapable conclusion is that planning of the electricity system carried out by a body having the attributes listed in Part 1 is essential.

4. The Renewables Principle

Arguments that are made to support this principle include:

- There are no fuel costs therefore the cost of production of energy from renewable sources must be low.
- There are no resource depletion issues.
- There are no CO_2 emissions at the generators.

Counter arguments to the Renewables Principle include:

- Wind energy: The severe intermittency of wind generation results in low capacity factors that lead to higher cost. Wind power cannot be guaranteed to be available when needed and therefore its capacity must be duplicated from sources that are reliable. Having two systems available for generation when only one of them (the reliable generation) is needed cannot be other than expensive. As the proportion of wind power in the system increases, problems of cost and security increase.
- Solar energy: As latitude increases, the efficacy of solar power declines. It also has an inevitable diurnal cycle and is greatly affected by cloud cover. Therefore, like wind, it needs to be backed up by a second source if security of supply is to be maintained. In high latitudes there is little prospect of it making a significant contribution to the electricity system.
- Hydro energy: Although there are some important environmental issues with hydro energy, it is cost effective and (with some reservations) reliable. However, although there is scope for further development of hydro power in some countries including the UK, the global resource for hydro is not large enough to make a significant contribution to world electricity production.
- Biomass: There are important environmental and social issues in relation to the burning of biomass but the fundamental problem is that, like hydro, the global resource is not large enough to make a significant contribution to electricity production.
- Marine (tidal and wave): Efforts to find a viable method of harnessing wave energy have proved to be unsuccessful. The efficacy of tidal generation has yet to be demonstrated.

Our conclusion: Critical issues in relation to these arguments are cost and scalability. It is unreasonable to expect that a method of generation will scale up globally if it costs significantly more than alternatives. The Department of Energy and Climate Change (DECC) has commissioned a study that will assess the whole system costs of methods of electricity generation. Studies of this type should precede decisions about the system.

It is clear that, on the basis of existing technology, it is not possible to have a fit for purpose electricity system based only on renewable generation. Decisions about appropriate levels of renewable generation must be based on the planned approach outlined in Part 1 of this document.

5. Experience of planning for electricity systems

5.1 The 1919 and 1926 UK Electricity Acts

In the early years of the 20th Century, the UK electricity supply was provided by a large number of small generators and there was no grid. The 1919 Williamson Report recommended that, in order to reduce the cost of electricity and improve security of supply, the sizes of generating sets should be increased and a national grid be established. After the Electricity act of 1919 there were 16 district authorities charged with planning the UK electricity system. These were toothless, and there was no recognition that the electricity system needed to develop quickly into a single nationwide entity. The reason why the 1919 act failed to achieve this objective was because it was felt that further regulation would represent too much intrusion into the electricity market.

Based on the recommendations of the 1925 Weir Report, the Electricity Supply Act of 1926, created a single powerful planning body, the Central Electricity Board. It had sufficient power to ensure it could meet the objectives set by a small group of Electricity Commissioners appointed under the Act. The Central Electricity Board built and owned the National Grid. It identified where new generation was required, but the new generation was owned by the generating companies. The new power stations were built to common engineering standards. Security of the system improved and electricity prices reduced.

Although the present technical problems with the electricity system are different from those in the early 20th century, there is an eerie resonance with the modern situation for electricity supply. Pre 1919 it was realised that the UK electricity market was not delivering as expected and a light touch solution (the 1919 Act) was implemented. Pre 2013 it was recognised that the electricity market was not addressing new capacity development and the light touch 2013 Energy Market Reform Bill was passed. Post 1919 it was realised that the light touch regulation was not working and post 2013 the same conclusion is evident because there is no market incentive to build thermal generators that are essential for system security. Such generators are closing down with no plans to replace them.

5.2 The North American experience

As a result of experience with electricity blackouts over many years, North America now has tight regulation of its bulk electricity supply by the North American Electric Reliability Corporation (NAERC). In the 1960's large regional Grids started to be interconnected. The industry developed a voluntary code to encourage reliability. An extensive blackout in 1965 in which 30 million people suffered a 13 hour loss of supply in the NE states and Canada, including the cities of New York and Toronto, prompted the establishment of the National Electric Reliability Council (NERC), who issued rigorous guides and criteria. On 13 July 1977 2.5 million people in the New York region experienced a blackout lasting up to 24 hours. There was considerable looting and public disturbance, causing the federal government to take an interest. Further major outages caused the federal government, in 2007, to make 83 of the NERC standards mandatory. NERC was renamed and was established as the ERO (electric reliability organisation) for the nation, answering to the Federal Energy Regulatory Commission (FERC). The powers of NAERC continue to be developed.

6. System Security

6.1 Ongoing assessment

The National Grid Company (NGC) is carrying out a major analysis of issues related to system security - see ref(2). That this study is being carried out demonstrates the growing realisation that engineering methodology must be applied to the electricity system.

However, these studies are not expected to be complete before 2018. In the meantime closure of thermal stations and introduction of further intermittent generation will increase the risk to security. It is evident that this assessment work should have preceded the changes to the system.

6.2 Security of operation

Ever since the national transmission system became completely interconnected in 1938, grid system operators have had the resources and procedures to maintain the integrity of the grid system. The grid system has evolved considerably over the years, as have the means of managing it. That evolution continues; so must the development of facilities required to maintain control.

There are two areas that require attention.

- A major factor in controlling system frequency is the inertia of the rotating parts of thermal generators, allowing the system to keep going while faults are cleared.
- Electricity systems can suffer from power oscillations, due to insufficient damping.

Currently both are contained using the capabilities of large thermal generators and their control equipment. A considerable tranche of steam turbine driven generators is due to be retired over the next few years, resulting in a loss of both inertia and system damping. Wind generators, solar photo-voltaic installations and direct current interconnectors do not provide this inertia.

NGC are supporting research to devise methods of keeping the system stable when system inertia is reduced. They are also creating a market in Enhanced Frequency Response (for improved frequency control during normal operation) and Fast Reserve (for post-fault frequency control). Neither initiative is due to be completed before 2018.

If plant is at risk it will be tripped out automatically. In rare cases this can lead to a regional blackout. Sustained unwanted oscillations can result in the current operating state being untenable, and manual changes are required to reach a viable operating state. In either case there will be adverse commercial consequences.

This issue is highly complex and can only be solved by detailed attention to the technical issues, as explained in references (2) and (3).

6.3 Security of supply

The 2013 Electricity Act acknowledged that market arrangements that had been in place were not adequately addressing security of supply. There was no market incentive to ensure that sufficient capacity was available to meet demand. A system of capacity auctions was put in place but these are now recognised as being inadequate and are being revised.

In order to have an optimum arrangement, the provision of energy and of capacity must be treated in combination as would be done using engineering planning.

7. The need for engineering methodology in planning the system

Under the present regulatory framework for the electricity system, bids are made to provide capacity to meet a security of supply criterion. As far we are aware, the decisions about which bids are accepted are not based on operability issues. But secure operation of the system is highly dependent on what types of plant are available and the locations of the plant (Section 6.2). In order to ascertain what plant should be where, it is necessary to carry out complex engineering calculations for different types of plant in different locations.

It is reasonable to ask the following questions with respect to this situation:

1. The electricity system has been privatised for over 25 years. During that time there has been no planning for the plant in relation to operability and we have had no major problems with the operation of the system. Why is engineering planning needed now?
2. The National Grid Company (NGC) is responsible for the operation of the system. Why not leave it to them to manage security of operation?

The answer to the first of these questions is that prior to privatisation in 1990, the system was very satisfactorily engineered for security of supply and operability. The private sector purchased a very robust system. Until quite recently the system had not changed much since that time. Now thermal plants, that have a positive effect on operability, are being closed and generators based on intermittent renewable energy, that have a negative effect on operability, are being introduced. The character of the system is being subject to drastic change. Only the use of engineering methodology can mitigate the emerging operational risks.

The answer to the second question is that NGC does have responsibility to seek to ensure security of operations based on the available generating plant. But it has no responsibility for ensuring that the plant mix is adequate. Since the plant mix is a critical issue in system security, the need for a body that does have such responsibility is manifest.

Tight regulation based on engineering methodology of the system would also resolve the problems with the Renewables Principle. Decisions about types of generation would take account of all relevant issues. The introduction of generation from renewable sources to the system would be based on judgements founded on reliable information

Professional engineers tend to achieve high success in contexts of complex uncertainty. At the core of their activities is a drive to reduce risk of unsatisfactory outcomes to as low a level as is practical. To achieve this, they use a range of strategies including predictive modelling, data gathering and analysis, option analysis, etc. Consideration of cost is a core issue in engineering.

The electricity system is a complex enterprise dominated by engineering issues. Not addressing these issues using the most advanced methods available, results in unnecessarily high levels of risk.

In other infrastructure sectors the Government uses engineering methodology and advanced risk control approaches. For example: The arrangement for risk control of the Crossrail project are described in reference (4). For the Queensferry Crossing presently (March 2016) being constructed over the River Forth, the Scottish Government set up a highly competent client team led by a civil servant who is an expert in the management of bridge engineering contracts. This team works closely with the contractors to seek to contain all risks.

8. Conclusion

Logic and evidence shows that engineering methodology must be reintroduced to planning for the Electricity System

References

1. Gibson C *An alternative to nationalization or privatization of the electricity supply industry in Great Britain* Renewable Energy Foundation, 2015 Available at: http://www.iesisenergy.org/CG-paper.pdf

2. The National Grid Company *System Operability Framework 2015* http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=44046

3. The National Grid Company *Enhanced Frequency Control Capability October 2014* https://www.ofgem.gov.uk/publications-and-updates/electricity-network-innovation-competition-submission-national-grid-electricity-transmission-efcc

4. Masterton G, *Engineers and Government - The case for improving strategic risk management,* IESIS, 2016 http://www.iesisenergy.org/sofs/Engineers-and-Government.pdf

IM 16.03.16