Embedded Generation in Transmission of Renewable Energy

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Abstract- *The concept of Embedded Generation in the transmission of renewable energy leads to the idea of exploiting all possible renewable resources at a particular site i.e. the build environment, in an attempt to meet the demand load. They consists of two generating components, Active and Passive renewables. Active renewables involves the direct conversion of renewable energy to electricity or heat i.e. wind turbines, photovoltaic, hydroelectric, geothermal, etc. Passive systems on the other hand are the second-hand energy, obtained from waste heat off of PV cells, day lighting or generally, energy obtained through any indirect means. Transmission of electricity over distances can incur transmission losses in the range of 5-7%. This figure includes losses from the transmission lines as well as substations and the associated electrical components. This is seen as a savings when the instance of transmission is reduced in embedded generation .This paper deals with benefits, scenario and issues of embedded generation.*

Keywords- Embedded generation, generators

I. INTRODUCTION

When the transmission distance is reduced, the construction cost of Substation, Transmission Towers and Right of Way would also be reduced or eliminated altogether. Especially in city centres where transmission is achieved through underground cables, there could be substantial savings involved as the cost of these cables can be 10 -20 times that of overhead lines. Also a benefit of embedded generation is the Corona Effect which is associated with overhead transmission lines. This involves noise disturbance and transmission interference to the surrounding population. The national electricity grid is saturated with supplies from existing power generators and by adding in extra amounts of electricity from renewable sources, this would only be wasted in the form of heat. It would be better if this generated electricity is used to satisfy a demand load as in an embedded generation scheme and the total energy consumption is reduced at the point of demand. The issue of stability and reliability of supply from the power electronics point of view can be improved in an embedded generation scheme as opposed to the supply of electricity over long distance. This is attained through shorter response time and better controls over the embedded systems. The ability to design the supply to match the demand as in an embedded generation scheme, again, would reduce unnecessary wastage as the demand profile is better defined for a smaller load than it is for supplying a whole region or country via the grid. Embedded generation offers an excellent option for the transmission of energy at the local level and coupled with the growing interest/research in renewable energy within the build environment, it would make a good combination in the way energy is generated and transmitted in the future current situation. The first electricity networks developed around 120 years ago as localized street systems and have evolved to become today's interconnected national transmission and distribution network. The UK electricity supply industry (ESI) has a structure characterised by:
* Large-scale generation plants
* High voltage networks
* Integrated generation, transmission, distribution and supply functions.

In recent decades Great Britain has relied almost exclusively on electricity generated by large power stations (e.g. the large coal stations constructed in the 1960s and the major nuclear stations) connected directly at 132kV and above. The distribution networks have been designed and operated to facilitate the transfer of energy from connections to the transmission system (Grid Supply Points – GSPs) to end users. In fixing price controls, setting licence obligations and monitoring system performance, electricity regulation has sought to ensure that networks are operated in an efficient, economic and cost-effective manner. Regulatory obligations are therefore closely linked to the current operating model for each type of business. Today's distribution networks operate passively delivering power from the transmission network.. This has resulted in passive networks with little embedded generation.

II. EMBEDDED GENERATION

Embedded generation is electricity generation which is connected to the Distribution network rather than to the high voltage National Grid. Embedded generation is typically smaller generation such as Combined Heat and Power (CHP) or renewable generation: small hydro, wind or solar power.

There are two ways electricity generators can feed into the electricity supply system;

1. At the level of the high voltage transmission network, i.e. into the National Grid. This is what all large generators do. This is known as centralised generation.

2. At the level of the lower voltage distribution network, i.e. into directly into Regional Electricity Companies' networks. This is known as embedded generation. A distribution network is the low voltage networkof wires and cables constructed to bring electricity to homes and businesses and operated by a distribution network operator (DNO), which, in this context, is a successor company to the former regional electricity companies. Embedded generation is generating plant connected to a local distribution system rather than to a high voltage transmission system. Most embedded generation consists of renewable or combined heat and power (CHP or 'co-generation') generators located on industrial sites, but other types of generating plant may also be embedded in distribution networks, including in the future micro-generation and domestic Combined Heat and Power (DCHP) technology. An electricity generation scheme is classed as an embedded generator if it is intended to operate while electrically connected to a PES's (Public Electricity Supplier) distribution network. This mode of operation is sometimes referred to as mains paralleling, as the generator operates while connected in parallel with the mains electricity supply. The generator may be directly connected to the PES's network or indirectly connected via a privately-owned network. It may export power into the PES's network or just offset part of a large onsite demand. In all of these cases, the generator operates in parallel with the mains supply, so the operator must comply with the statutory requirements applying to embedded generators..

2.1 Demand of Embedded Generation and Increasing Requirement.

Since the late 1980s, there have been significant changes within the ESI, such as the liberalization of electricity markets, technological advances, tighter financial/lending constraints and increased environmental concerns. Each of these, to some extent, has fuelled interest in low-capital, small scale, fast revenue generating projects, such as modern gas-fired power stations (combined cycle gas turbines, CCGTs), wind turbines and CHP plant.

The following factors have contributed to the present consideration of embedded generation:

- Growing competition in the electricity generating market, including from new entrants.
- The Government's environmental targets, reflecting obligations under the Kyoto Agreement, to achieve10GW of CHP by 2010 and to generate 10% of electricity from renewable sources by the same date.
- The new obligation that the Utilities Act 2000 placed on distribution network operators (DNOs) to facilitate competition (formerly, only transmission operators had been under such an obligation).
- Pressures for increased network reliability, at reduced cost to customers.
- Perceived environmental as well as economic benefits of locating generation close to demand.
- The desire to secure cost savings by avoiding transmission charges.

Embedded generation growth is motivated by improved efficiency in smaller capacity generation and co-generation plants, along with a greater emphasis on renewable generation. In addition to purely economic generation, encouragement of renewable or green energy has become more important for other reasons. The Non- Fossil Fuel Obligation (NFFO) was introduced by the government for England and Wales, with similar schemes in Scotland and Northern Ireland. NFFO fuel sources are as follows:

- Hydro
- Municipal and industrial waste
- Sewage gas
- Wind
- Landfill gas
- Biomass
- Other (including solar and wave)

Wind power offers the cleanest and safest commercial method of generating renewable energy, and the UK has the largest wind potential in Europe, from both onshore and offshore wind farms. The Government has set targets for increasing renewable energy and CHP. It also wants the UK to be at the forefront of the liberalisation of electricity markets and the promotion of advanced technologies to enhance competitiveness and provide greater opportunities for the growth of overseas markets for energy technologies and services.

2.2 Problems with Embedded Generation

Embedded generation poses a number of technical and contractual challenges to distribution network operators. Technical issues include: ensuring compatible feeder protection and auto-reclose schemes; network voltage control with varying generator output; earthing design; and dynamic stability of generators during network faults. Contractual aspects involve ensuring open access to the network, allocation of network development costs between generator connection and future load growth, and generator connection charges.

2.3 Barriers to Embedded Generation

Currently, anyone wanting to connect to a distribution network would have to pay 'deep' connection charges. This is a one-off, up-front payment to allow generators to connect to the networks. It covers the cost of strengthening the network associated with the export of new generation up to the transmission networkboundary. As many renewable projects are located in remote areas, these costs can be prohibitive. Demandcustomers i.e. those who use electricity rather than produce it pay 'shallow' connection charges whichinvolves paying for the equipment needed just to connect to the local part of network. Planning permission and financing pose problems to renewable developments, and the high cost of connections to distribution networks is a major block to increased penetration of renewable energy sources. Several existing and prospective embedded generators suggest that they are at a relative disadvantage compared with those connected to transmission systems.

2.4 Advantages of Embedded Generation

Embedded generation can bring a number of advantages over centralised generation, but the extent of the advantage depends on where the embedded generator is located in the network. Embedded generation brings most benefit where the transmission and distribution grid is weak.

This occurs in areas which are remote from centralised generation plants.

1. Advantages of embedded generation over centralised generation basically, embedded generators deliver electricity to consumers in a more direct way than centralised generators. The electricity is generated in closer proximity to the user, reducing the distance over reducing electrical losses. (Electrical output from centralized generators has to be transformed up to a high voltage, transmitted, and then transformed back down to the lower voltage).

2. Environmental benefits: If less electricity is lost in transmission and distribution, then less has to be generated.

3. Strategic benefits: Embedded generators can help prevent power cuts. If there is a partial failure on the high voltage network then an operating wind farm can prevent local customers from a power cut.

4. Economic benefits: The monetary value of embedded generation using the high voltage transmission network costs money. Embedded generators do not use it, and so save money.

5. The cost of electricity increases as it moves through the system. This is due to a variety of physical factors, such as transmission and distribution losses, and institutional factors, such as charges. Electricity from embedded generators, such as wind farms, enters the system at the 33 kilo Volt level. An explanation of some of the factors which contribute to the increase in the cost of electricity as it moves through the system is given below.

- Transmission losses: Around 2% of electricity is lost during transmission on the national grid. This therefore adds around 2% to the price of electricity (which is around 3.9 pence/kWh as it leaves the grid), i.e. an extra 0.078 pence/kWh.
- Distribution losses: Around 7% of electricity is lost during distribution on the RECs network. The extent to which embedded generators help avoid distribution losses will vary according to their location. Sometimes the savings will be substantial. Although it is also possible that an embedded generator could increase distributionlosses in some circumstances, e.g. if there is already a substantial amount of embedded generating capacity in the locality.
- Triad charges/Transmission use of system charges.
- The National Grid Company charges electricity suppliers for the use of the high voltage transmission network. The charges are known as triad charges, because they are calculated during the three half hours of the year with the highest electricity demand. The level of the charges depends upon geographical location, ranging from £5 to £17 per kW of demand.
- If the REC can show it purchased X amount of electricity from sources which are not subject to the levy, then it is exempt from paying the levy on X. This is worth 0.6 pence/kWh.
- An important aspect of the certificates is that the REC is allowed to adjust the value of X to account for savings on distribution losses. For example, if the REC purchased X MWh of non-liveable electricity, which saved say 5% on distribution losses, the REC would be avoid paying the levy on 105MWh of electricity.

III. EMBEDDED GENERATION ISSUES

Quality of supply can be considered to have three elements:

- Reliability - long and short term interruptions of power supply;

- Power quality **-** frequency and voltage stability, waveform abnormalities; and
- Service **-** response time, restoration time.

The advanced electronic equipment found in modern working environments, often requires a high level of reliability from the incoming electricity supply. For example, today's complex manufacturing processesrely heavily on microcomputers, variable-speed drives and robotics devices to achieve high levels of product throughput and product quality. This leads to increasing expectations of electricity end consumers, who place increasing demands on electricity suppliers to meet the demand for quality of supply. Evidence for this is given by the large market for power quality measurement and analysis systems. National regulations dictate the minimum quality of electricity and, if these are complied with the requirements of most consumers willbe met. In the case of consumers with special requirements or in areas where quality measurements give rise to concerns, there are methods of ameliorating shortcomings in the electricity supply. However, some of these methods can themselves have an effect on the supply network.

IV. GRID GENERATION

The UK transmission and distribution system is characterised by a 400kV Grid Transmission System which delivers large flows of power through bulk supply points to the low voltage Distribution networks providing 230V to the consumer. The nature of a considerable amount of the central generating capacity connected to the Grid is such that it provides voltage and frequency support to the electricity supply. However, there is an increasing use of combined cycle gas turbine (CCGT) generators which require an auxiliary source of power to have 'black start' capability and which usually don't provide frequency support for economic reasons. This lack of support is expected to be exacerbated by the increased use of generators powered by fluctuating (stochastic) renewable energy sources e.g.Wind and tide. A technical solution for this is to hold a greater frequency responsive reserve and/or contracting for Black Start support but how is this to be paid for? The economics of providing support needs to carefully address by NETA. The formula used under the existing Pool arrangements results in capacity payments which are highly sensitive unforeseen demand and to the withdrawal, for whatever reason, of particular generating plant.

V. DIVERSITY OF EMBEDDED GENERATORS

The design of Distribution Networks below 132kV has been optimized over many years to distribute electricity in a single direction at the lowest cost. By definition, embedded generation is not connected to the Grid but embedded within the Distribution Network Embedded generation can create a power flow which runs counter to the 'tapering down' of the distribution network. Limitations on reverse power flow through transformers etc means that, unless it is reinforced, the Distribution Network becomes progressively less capable of supporting embedded generation as one gets closer to the consumer. The range and nature of existing embedded generators is considerable. A 400MW coal- fired station built in NE England to power an aluminium smelter regularly provides around 180MW of backup power to the electricity market. The industrial situation at the time (1970), made it financially and operationally attractive to build the smelter and station and reinforce the local distribution network to use the 'excess' electricity. This demonstrates the need to consider the local use of electricity as well as its generation. At the other extreme, individual wind power installations capable of routinely supplying a few megawatts, are usually situated on the coast or on remote hill tops i.e. at the fringes of the Distribution network. CHP installations are usually located away from the fringes but can be difficult to accommodate because they can be supplying or consuming electricity, depending on the season and the time of day. If Distribution Networks are to accommodate increased quantities of embedded generation then they will need to be managed as 'active' rather than 'passive' systems. This not only means installing complex control systems, but also equipping transformers with tap changers that can control voltage locally. If the cost burden that different sources of generation impose on Networks is not appropriately recognised by the charging arrangements, then the most efficient Network/generator configurations are unlikely to be implemented and charges to customers will be higher than need be.

VI. ENERGY STORAGE

The generating capacity available must be able to meet the peak demand and, as demand is below peak for most of the time, a significant amount of capacity is under-utilised. It has been estimated that the average utilisation of generating capacity is around 50%. One way of improving generator utilisation is to use 'off peak'electricity in energy storage schemes. The energy stored can then be used to generate electricity at times of peak demand. There are some very large schemes e.g. the Dinorwic pumped hydro scheme, associated with the grid. Despite there being suitable technology available e.g. regenerative fuel cells, as yet there is little storage in the supply chain. It is often considered that renewable generation is of two types, despatch able and stochastic. Despatch able generation, such as conventional hydro or that powered by biofuels, can be made to provide electricity in a manner which is related to demand. Stochastic generation, such as that powered by wind or wave, fluctuates in a manner which is unrelated to demand. However, stochastic generators can provide electricity which contributes coherently to the demand cycle, if they are associated with appropriate energy storage systems. Atmospheric Co2 One reason given for the need to generate more electricity from renewable sources is to reduce CO2 emissions, however, the following should be considered.

6.1 Renewables and CO2

Some renewables e.g. hydro, wind, wave, solar, geothermal, do not produce CO2 but others eg biofuels and waste incineration, do produce CO2. It is argued that the amount of CO2 released when biofuels are burned. Approximates to that consumed when they are produced thus, over a given period, the net contribution to atmospheric CO2 is zero. However, this ignores the contribution to random peaking of atmospheric CO2.Also, unless the combustion process is tightly controlled, particularly in waste incineration schemes, there can be far more dangerous products e.g. dioxins.

6.2 Reducing Nuclear Generation

Nuclear energy at present provides around 25% of the electricity supplied in the UK and does not contribute to atmospheric CO2. If nuclear generation were to be replaced by its equivalent in renewables, these would have to be 'carbonless' and non-stochastic. This could only be achieved with hydro and geothermal or by using wind, wave and solar associated with appropriate energy storage systems.

6.3 Combined Heat & Power (CHP)

CHP prime movers are usually sized by their base load heat demand. Their overall efficiency and commercial success depend on the combination of heat transfer efficiency and electrical generation efficiency, and the demand cycles for electricity and heat. Thus, CHP is not necessarily more efficient than the alternative of standalone heat and grid supplied electricity. CHP is most attractive when the price of grid electricity is high and fuel for the prime mover e.g. gas, is low.

VII. CONCLUSION AND FUTURE SCOPE

Substantial embedded generation would require more active distribution networks which allow electricity to flow in two directions – to the electricity user for consumption in the home or business, and on to the network when the user is exporting excess generation capacity. This will result in distribution networks being able to export as well as import power and there will be a need for operators to more actively manage their networks and to address new technical requirements. The more embedded generation there is, the more need there will be for operators actively to manage the power flows on their systems.

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