IMPACTS OF DISPERSED GENERATION TECHNOLOGIES ON RELIABILITY OF ELECTRICITY SUPPLY

I. Kromer, Z. Bessenyei
Institute for Electric Power Research
Gellerthegy u. 17.
Budapest, Hungary

Abstract: **Installation of heat and electrical power generating units based on locally available sources and matched in size to customer needs is one possibility to meet the energy needs of the world required for sustainable development. In this paper the technologies suggested for local or in other words dispersed generation are introduced and their impacts on reliability of electricity supply are evaluated.**

I. INTRODUCTION

The world energy consumption and production are based to large extent on hydro-carbon sources. The amount of available hydro-carbon is limited, its price is continuously increasing in spite of development of drilling and refinery technologies. The most important origins are in countries where political instability and social conflicts may jeopardize their production and supply of consumer countries. The nuclear power – though share of NPPs in the world electric power production is not negligible – has become off-color. There is not breakthrough in development of fusion reactors. The technologies for utilization of renewable sources which are available theoretically unrestrictedly are usually expensive ones and some times they have side-effects damaging the environment.

Unfortunately these facts have known in the printed and electronic media and among professionals for decades without pregnant improvement. The large black-outs of the last years have turned the attention to the vulnerability of large distribution grids and to necessity of re-thinking of the out-of-date protection solutions and philosophy.

Having the increasing number of issues to be solved and beside this the new economic situation caused by the market liberalization a new-old technology got into focus of rulers and actors of electric power market [1]. This new-old technology is the dispersed or distributed generation which means heat and electric power production using locally available resources and small unit power usually from a few hundreds W up to 10 MW. The appreciable development has led to technologies and equipment which may be consumable for users from commercial moreover from residential sectors not only for industrial users. The development of protection and generic I&C technology make possible not only the islanding way of operation but also the feeding to the distribution grid. The up-to-date IT solutions make possible the remote control of generating units and grouping them. Groups are able to carry on active energy trading. Of course this “active” consumer generates not only electric power but technological, legal and commercial issues to be solved by the utilities and regulators.

Political decision makers, research institutions and manufacturers have expended and are expending significant resources to solve the issues listed above. In the frame of FP4 and FP5 the EU had financed 65 projects dealt with development of dispersed generation and its economical and social affects. In the frame of FP6 there are 14 integrated projects connecting to “energy”. Furthermore there are four Network of Excellence with topics related to power production and storage (hydrogen as a safety energy resource, nano-materials for energy storage, application of bio-energy, carbon-dioxide storage).

II. DISPERSED GENERATION – ACTORS AND MOTIVATIONS

The mass deployment of dispersed generation may happen only along the interest of all actors, who may be grouped:

1) Consumers in industrial sectors: members with high energy consumption have produced heat and electricity for decades if they had got cheaper primary energy source (e.g. combustible gas as side-product of their production) or if their technology had needed extra safety of supply. The possible cost reduction as a very important motivation in the industry generates further needs and the developing generating technologies and decreasing unit prices help the realization. In this range the skills and additional infrastructures that necessary to operate a DG unit and to manage the grid connection are usually available.

2) Consumers in commercial sectors: hospitals and office building – they are typical members of this group – have operated emergency power sources for a long time. The need for cost reduction and the development of technologies make the local heat and electric power production alluring. Selling of the energy producer over their own needs is a good option but the lack of necessary skills usually may be realized with difficulties.

3) Consumers in residential sectors: members of this group need as cheap energy as possible but like their traditional “supplied” status too. Because of lack of skills this group needs plug-and-play solutions. Operation of a "domestic power plant" must not be more complicated than the operation of a dishwasher or a common gas-boiler. According to a small-scale representative poll done by VEIKI in 2005 the respondents refused the possibility of remote control which is an important term.

4) Members of traditional electric and heat power supply systems, TSOs, utilities, power plants: the dispersed generation harms the interest of classical power plants. For TSOs the system supervision becomes more difficult but there are technical solutions to overcome the difficulties. The collateral costs may be compensated by charging the newcomer vendors e.g. the owners of DG units. In first readings the utilities loose, but they are able to acquire some kind coordinator function. Coordination of individual DG units seems to be necessary to achieve better market position. District heating penetration varies country by country and region by region. Replacement of the traditional heating plants with combined cycle units may result some extra profit being the price of the co-generated power subsidized in most cases.

5) Manufacturers: the most motivated group of actors. The motivation is materializing in releasing products which are not really matured and not perfectly matches the needs of the target group of users and – that is more important – in huge amount of money spent on technology and product development.

6) Vendors of primary energy sources, gas utilities: most of the DG technologies which are matured for real application are natural gas based. It is evident that the gas utilities try to extend their market undertaking even the financing of developments.

7) Political decision-makers and regulatory bodies: who are able to affect the power production and energy consumption setting and modifying the rules, and who are tried to be affected by lobby organizations of the groups mentioned above. Decision-makers are taking account first of all the sustainable development, international agreements (for example the Kyoto agreement) and aspects of the environment protection. Decision-makers are expected to support technologies based on renewable sources and which are environmentally sound.

III. TECHNOLOGIES

Before evaluating the impacts of mass DG penetration on reliability of electric supply a short review of technologies is necessary. Emerging the dispersed generation has affected the traditional grid. The operational features of a given DG technology tint further the picture.

The most important features of dispersed generation are:

1) The produced power mainly used locally and the generation usually combined with heat energy.

2) The typical power range is under 10 MW, for residential users there are – or planned – equipment around 1 kW.

3) The market liberalization makes easy the selling of superfluous power by law, but technically there are several issues to be solved being the connection most often happens on low or medium voltage level to the distribution grid.

4) In the lower power range – typically commercial and residential consumers – the DG often combined with heat or electric power storage facility to make possible the operation of the unit near to the nominal power level achieving the highest possible efficiency.

Typical generating technologies are:

1) Small steam turbines with boilers fuelled by arbitrary fuel which is available on the site. Popular solution for large industrial consumers. CHP option can easily be realized. Using combustible waste or side-product gases further benefits are available.

2) Small gas-turbines. A few decades ago they worked mainly as emergency sources. Nowadays having higher efficiency – first of all with CHP option – they are used for continuous production too.

3) Reciprocating engines. The traditional diesel emergency units are able for continuous operation, and their reliability is high, but because of the high price of diesel oil this DG solution loses its grip. At the same time the natural gas fuelled reciprocating engines with CHP option are very popular. The high combined efficiency, relative low emission rate and the reliable operation bolster up the popularity.

4) Micro-turbines. They are featured with simple but relative reliable mechanical design – single shaft, air bearing, and permanent magnet generator – and high rotating speed. Solid state inverter is used to produce high quality power. CHP option is available. They are usually fuelled by natural gas. Hydrogen and cleaned bio-gas are also applicable.

5) Stirling engines. A rediscovered technology. The working material is heated up externally. There are not exhaust gases, the engine does not need oxygen. The environmental impact is determined by the external fuel and heating units. In the cleanest version the sun shine is used for heating. Their efficiency is very high it is near to the theoretical value of Carnot cycle.

6) Wind mills. This is the simplest and cheapest generating technology based on renewable source. The noise and the unpredictable behavior of the wind are disadvantages.

7) Fuel cells. Emerging technology. The units may be fuelled by hydrogen or natural gas. Practical applications are mostly based on natural gas. Wide power range, high efficiency, CHP possibility are the most important features. Main disadvantage is the short lifetime.

8) Photo-voltaic panels. Clean, green, scalable technology. The price and low efficiency are the disadvantages. Because of the low output voltage of cells several cells are ordered into panels and panels are also combined. Additional storage and solid state inverters are necessary to build up a local power unit. Over emergency applications commercial and residential users up to a few kilowatt power needs are targeted.

Table1 contains a review of possible fuels. In Table2 some operational features are gathered which determine the impact of a given technology on reliability of supply.

TABLE1
DG TECHNOLOGIES AND THEIR TYPICAL FUELS

Technology	Oil	Kerosene	Natural gas	Bio-gas	Bio-mass	Hydrogen	Solar	Wind
Small steam turbines & boilers	☻		☻	☻	☻			
Gas-turbines		☻						
Reciprocating engines	☻		☻	☻		☻		
Micro-turbines			☻	☻		☻		
Stirling engines			☻	☻			☻	
Wind mills								☻
Fuel cells			☻	☻		☻		
Photo voltaic panels							☻	

TABLE2
DG TECHNOLOGIES – OPERATIONAL FEATURES

Technology	Continuous operation	Quick start-up	On/off operation	Additional storage necessity	Continuous availability of the fuel
Small steam turbines & boilers	Y	N	N	N	Y
Gas-turbines	N	Y	N	N	Y
Reciprocating engines	Y	Y	N	N	Y
Micro-turbines	Y	Y	N	A	Y
Stirling engines	Y	Y	Y	N	Y
Wind mills	Y	Y	Y	Y	N
Fuel cells	Y	N	N	A	Y
Photo voltaic panels	Y	Y	Y	Y	N

Agenda: N: not, Y yes, A: advisable

IV. Reliability of Electricity Supply

While liberalization of energy markets is resounded by stakeholders large scale blackouts causing society level trauma and showing the vulnerability of the electricity systems have fed concerns of the governments, legislators and general public regarding the reliability of the electricity supply. The electricity plays an essential role in the everyday life and the importance of the reliable, high-quality electric services has further increased in the last years having more and more sophisticated and sensitive manufacturing processes, control and instrumentation technologies in the industry and more and more electricity driven equipment everywhere from households to hospitals and offices.

By definition system reliability is the degree to which the performances of the elements of the electrical system result in power being delivered to consumers within accepted standards and in the amount desired. This definition and similar ones too encompass two conceptual pillars: adequacy and security.

1) System adequacy is defined as the ability of the system to supply the aggregate electric power and energy requirements of the consumers at all times [2].

2) System security is defined as the ability of the system to withstand sudden disturbances.

Both pillars are impacted by the presence of dispersed generation. Of course the importance of the impacts depends on the level of DG penetration. The mass penetration hoped is around of 10%. This level is easily manageable on system operation level and may increase the system adequacy and security too. From point of view of the adequacy the reserve capacity increasing – without any investment to the traditional system – and system load decreasing must be mentioned. From point view of the security the vulnerability of the system is decreasing, meaning that the affects of a possible terror hazard and extreme weather conditions are reduced.

Due to the uncertain investment climate, lower costs and shorter project time the dispersed generation is more attractive than building large power plants. As far as the risk of cascading failure [3] becomes significant at or above a critical system loading – decreasing the average system load – dispersed generation can improve the security of the grid.

However transforming the centralized power system into something closer to a smart distributed network to provide reliable power supply and to make possible innovative new energy services may seem like a return to the electricity's roots a century ago.

The emergence of micro grids is apparent, however it is not a complete return to that model but the promising sign of a smart future energy system coupled with the rapidly developing information and communication technology.

V. Conclusions

The DG investments motivated by the needs of increased reliability have got two folded benefits. On the one hand the load on the grid decreases, on the other hand the consumer defines the level of reliability that he needs. In this situation the local power generation partly reduces the responsibility of the grid operator giving a possibility to operate a less reliable grid and to reduce operational costs.

The small and dispersed power generating units are decreasing the effects of disasters and terror hazard. Nevertheless it must be mentioned that the most popular DG technologies are based on natural gas. So the benefits in the reliability of electricity systems may be achieved if the savings partly will be invested for enlarging the capacity of gas distribution systems.

The listed benefits will be realized on the side of the owners of dispersed generation sites. In contrast the realization of benefits on grid level seems to be more doubtful.

References

[1] I. Krómer, "Energy strategies in a liberalised electricity industry," Eleventh International Conf. on Electrical Machines, Drivers and Power Systems, ELMA 2005, Sofia, Bulgaria

[2] V. C. Sulzberger, "Transmission expansion and adequacy issues," Transmission Network Performance in Competitive Electricity Markets, Paris, France, 2004.

[3] I. Dobson, B. A. Carreras, D. E. Newman, "Probabilistic load-dependent cascading failure with limited component interactions," IEEE Int. Symp. on Circuits and Systems, Vancouver, Canada, 2004.