DEFINING IMPACT OF DISTRIBUTED GENERATION ON POWER SYSTEM STABILITY

A. M. Guseynov, B. S. Akhundov

Azerbaijan Scientific Research Institute of Energetics and Energy Design

ABSTRACT

A principle of distributed generation, for the moment loosely defined as small-scale electricity generation, is outlined with reference to modern technologies in the power systems. Their significance and advantages are demonstrated on an example of the Azerbaijan power system; impact on the power system operating conditions and stability is assessed in the paper.

Keywords: defining impact, distributed, generation, power system, stability.

I. INTRODUCTION

In addition to establishment of large-scale united power systems and powerful power stations, long overhead transmission lines as well as transition to the market relations in the power engineering the objective tendencies in development of the power systems in many countries worldwide resulted in creation of a principle of distributed generation (DG). DG is defined as supply to consumers remotely located from the central power supply system through small-scale electricity generation.

A wide range of the distributed generation units distinguished for their operating features, fuel type, power and efficiency ratings and cost implications have come to the market due to necessity to supply remote locations. Amongst DG units one can name internal- and external-combustion engines, gas-turbine and steam-turbine units, and those based on utilisation of renewable energy.

As a rule the units rated up to 3-5MW are most commonly connected to the internal consumer power supply network, and those rated above – to the external power supply system. The distributed generation units (DGU) have already been classified in relation to their power rating (1). A classification is presented in Table 1.

Table 1.

Type of DGU	Power Rating range
Micro DGUs	**1 watt < 5kW**
Small DGUs	**5kW < 5MW**
Medium DGUs	**5 MW < 50 MW**
Large DGUs	**50 MW < 300MW**

The distributed generation principle has a number of advantages (2).

1. Power supply reliability enhancement for consumers remotely located from main power supply system.
2. Power supply independence for consumers is provided
3. Opportunity to utilise local energy recourses
4. Main power supply system is unloaded
5. Power supply reserve in the power system is reduced
6. Load peak is becoming smoother
7. DG meets criteria of power supply security provision
8. Power loses reduction due to reduction in transmission lengths
9. Reimbursement of a part of expenses to remote power plants supplying remote consumers is no more required

II. MAIN PART

The last two bullet points contribute to compensation of the relatively high cost of the DGUs.

Efficiency of introducing DGU depends on operating and topological peculiarities of every given power system. The paper aims at assessing technical efficiency of introducing the principle of distributed generation in the Azerbaijani power system.
The Azerbaijani power system is characterised for its disproportion in "generation - consumption" areas in the structure of the power supply system.
Despite mentioned advantages, a process for introduction and development of the DGUs is not that simple. There are a number of problems as stated below (2):

- Significant difference in operating conditions / parameters of the DGUs from units installed at powerful plants which will have to be operated in parallel – and this may adversely impact overall stability of the power system
- Issues related to connection to the main power supply grid
- Complexity in voltage regulation at lower ranges and their incompatibility with the overall voltage regulation system of the power grid
- Controlling methods – particularly protection system management of DGU against power grid, i.e. protection coordination, grading, etc.

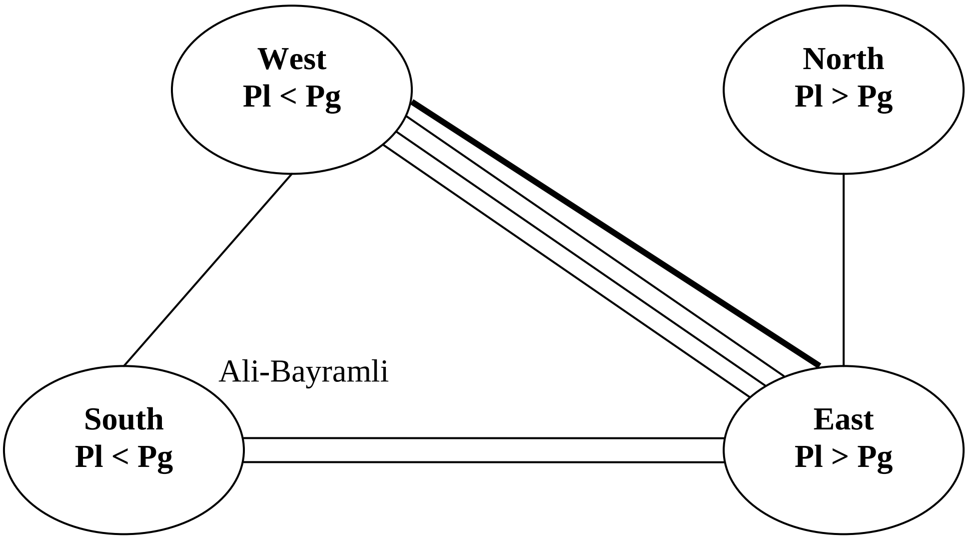


Figure 1. Regional structure for "generation – consumption" of the electric power

Table 2.

Parameters	Units	Options		
		1	2	3
Total power losses (transmission)	%	4.7	3.7	3.6
Loading at the main heat power plant in the West	MW	1634	1594	1487
Static stability reserve on line 2	%	22	25.8	28.3
Static stability reserve on line 1	%	7.3	10.7	12.4
Average voltage level in the region (North sub-station)	kV	96.2	116.1	117.1

Figure 1 shows a simplified scheme of the structure. The present distribution of the generation sources, availability of "area discontinuity" as well as generation and load concentration cause unsatisfactory voltage quality in the

Northern regions, high dependency levels of consumers located in the East (Apsheron) from power transmission from the West through HV overhead transmission lines (220-330-500kV, 300km) – /Mingyachaur – Apsheron/. The lines themselves are not sufficiently rated to provide necessary power capacity, high power losses, etc.

In 1994 the power generation in the Azerbaijan power system totalled 94% vs 1990's level, but demand was

With due regard to above stated, the State Energy Program for 2005-2015 stipulates not only building and commissioning of high-capacity combined-cycle plants (400-500MW), but also putting into operation 52 off DGUs on the base of the 8.7MW units supplied by Wartsila (Finland) to total capacity of 450-460MW. To accommodate such the units in the power system of Azerbaijan it was required to study impact of the DGUs on the power system and assess overall system stability under different operating conditions.Within next few years it is expected that load will rise up to 4,600MW and to meet such demand it is required to introduce additional 400MW of generation.

The gap can be filled by installation of an extra single power unit in the Eastern region that is currently experience a high deficit in power energy (Option 1).

Another approach (Option 2) would be to locate DGU in the North-East and South regions – 4 x 100MW. The third solution incorporates both options.

Table 2 is complied to provide comparative analysis of results of the studies and show some parameters of the operating modes and static stability.

The results of the study clearly demonstrate that introduction of distributed generation principle in the power system reduces losses in the transmission facilities because of unloading, the most powerful station on the West is getting unloaded (about 40MW become available for export at AzGRES), DC transient static stability on the line 2 (West to East) improves and voltage level on the North substation cardinally improves.

Hence, introduction of DGU in the Azerbaijani power system leads to improvement of the operating conditions and DC transient static stability reserve. However, the results of studying dynamic stability of the system after introduction of DGU are not so much optimistic. It is known that dynamic stability of any system is assessed based on relative "movement" between generators at high distortions. Amplitude of oscillation or relative acceleration between generators ($\frac{d^2\delta_{ij}}{dt^2}$) depends on measure of discrepancy of the generators' inertia constant, value of impedance between the generators (direct link), impedance through the system (indirect link) and loading prior to distortion in the system.

The commissioning of a power plant comprising 10 units (each rated at 8.9MW) is close to completion in none of the regions of Azerbaijan (Astara). The connection is done via step-up transformers to nearby 220kV substation belonging to the power grid. The DGU's inertia constant is just 0.3 sec(the generators presently operated in the system have inertia constants of 5 seconds and above). 110%. There is a hunger to build and put into operation large-scale power supply units (400-500MW) under present circumstances of intensive power consumption growth. In the run of their construction the demand for electric energy is getting even greater, and the problem of electric power quality in the regions remains open.

At the same time, less than a year is required to build and commission units of distributed generation.

The value of this parameter may cause inadequate reaction in nearby nodes of the system to any distortion, especially at the DGU substation.

A fault level analysis has been conducted to better understand impact of distortion to DGUs and its nearby consumers. In particular, a two-phase fault to earth has been modelled at busbars of one of nearly located substation (220kV substation at Ali-Bayramli GRES /power plant/). Following the results of the study it was defined that to keep the system stable after such the distortion and achieve minimal impact it is necessary to isolate faulted area within 0.11 sec. ($t_{critical}$), whereas, if DGU are not connected – 0.76 sec would be sufficient.

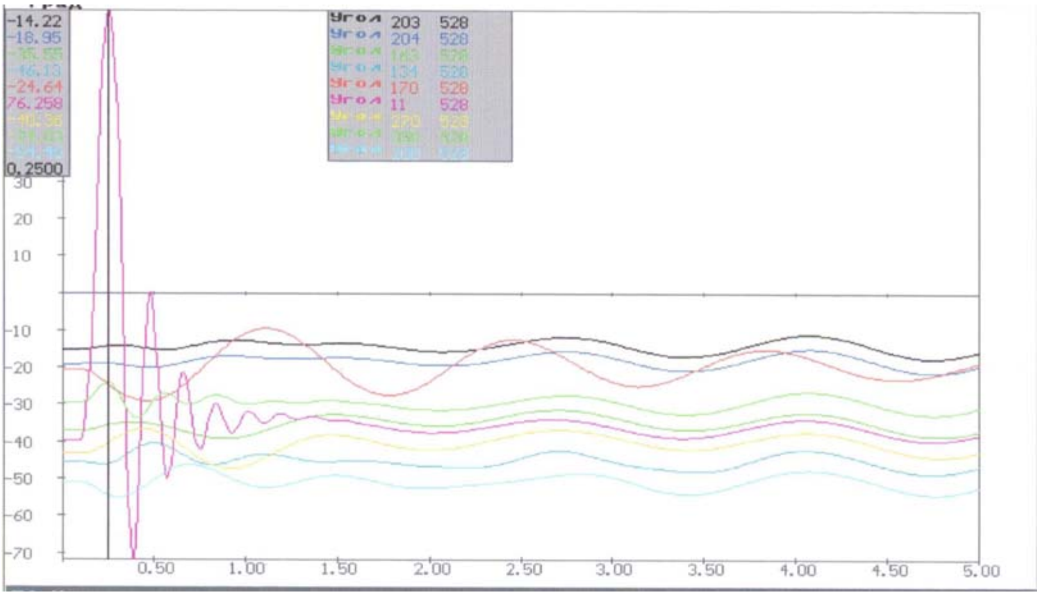
Figures 2 and 3 show transient process development at given distortion type for $t_{critical}$ = 0.11 sec and for $t > t_{critical}$ (0.12 sec). Analysis of the transient process shown on the figures clearly demonstrates the following: if faulted area is disconnected / isolated in t = 0.11 sec (Fig. 2), the oscillating process that has dynamic amplitude (initial) would damp in about 1.25 sec, and this would not affect oscillation of rotor angles of other generators in the system. This is due to the fact that power capacity of the DGU is small compared to the overall power system capacity (2%).

Figure 3 shows unstable behaviour of DGU's rotor angle at $t > t_{critical}$. A sharp reduction in critical disconnection time under operating distortions identifies necessity of correcting settings at some of protection devices.

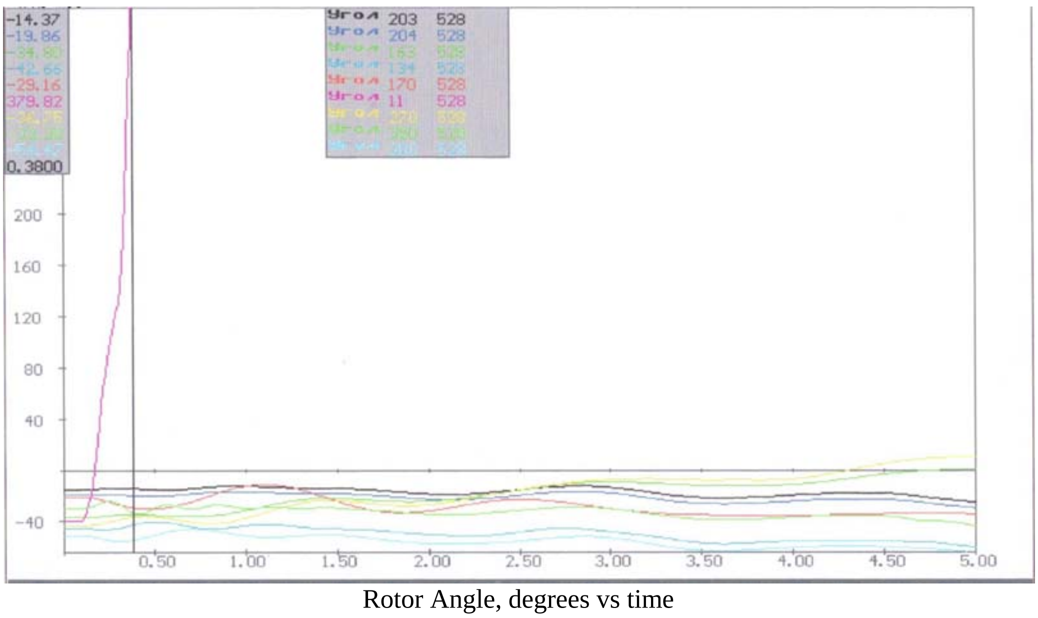
A comprehensive analysis shall be completed prior to installation of power plants with DG units in the system. This may affect stability of the system and give grounds for defining acceptable level on power capacity of such Distributed Generation units in the power system.

III. CONCLUSION

- The principle of distributed generation has been developing thanks to a whole range of advantages enhancing power supply reliability and quality.
- Application of DG principle in the Azerbaijani power system allows unloading main electrical distribution grid, reduce power loses and provide necessary voltage level at consumption nodes, as well as, increase reserve of DC transient static stability.
- At the same time it is worth pointing that introduction of power stations equipped with DGU deteriorates dynamic stability of the system, and this necessitates checking efficiency of settings of protection system during significant power system distortions.



Rotor Angle (degrees) vs time
Figure 2. Two-phase fault on busbars of 220kV Ali-Bayramli power station
Shunt impedance = 2.37Ohm
Critical disconnection time = 0.11 sec



Rotor Angle, degrees vs time
Figure 3. Two-phase fault on busbars of 220kV Ali-Bayramli power station
Shunt impedance = 2.37Ohm
Critical disconnection time = 0.12 sec

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