THE MICROGRID SYSTEMS: AN OVERVIEW IN TURKEY AND THE WORLD

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ABSTRACT

Necessity and important of electric energy has been on increase because of development in technology and economy. When compared with renewable energy sources, electric energy obtained from fossil fuels has the biggest share. But demand to renewable energy sources has been increased instead of fossil fuels due to carbon dioxide emissions, risk of being used up over and above high energy cost. Distributed energy sources (wind energy, solar energy, fuel cell, etc.) can be installed to close areas to consumers. So distributed energy sources with microgrid design can be used as cost effective, reliable and efficient. Micrograds are small scale energy network that can provide uninterrupted energy with high power quality to different types small load community and can meet technological preferences of consumers so power quality demand. Microgrid systems in interconnected to distribution grid or islanded mode; obtain coordinated operation of energy sources (micro turbines, fuel cells, photovoltaic, etc), storage devices (flywheels, energy capacitors and batteries) and loads. In this study, potential of microgrid system in Turkey and world, technological development at microgrid systems and usage state of these technologies in Turkey and world were evaluated. It was exhibited that attaching importance to microgrid systems provides increment in usage of renewable energy.

Keywords: *microgrid systems, distributed energy sources, renewable energy*

ÖZETÇE

Elektrik enerjisinin gerekliliği ve önemi teknoloji ve ekonomi alanındaki gelişmelerden dolayı artmaktadır. Yenilenebilir enerji kaynaklarıyla karşılaştırıldığında, fosil yakıtlardan elde edilen elektrik enerjisi daha büyük bir orana sahiptir. Ancak yenilebilir enerji kaynaklarına yönelik talep, karbondioksit emisyonu, yüksek enerji masraflarıyla kullanılma gibi risklerden dolayı fosil yakıtlara göre daha fazla artmıştır. Dağıtılmış enerji kaynakları (rüzgar enerjisi, güneş enerjisi, yakıt hücresi, vb.) tüketicilere yakın alanlara kurulabilir. Dolayısıyla mikro şebeke tasarımına sahip dağıtılmış enerji kaynakları uygun maliyetli, güvenilir ve verimli bir şekilde kullanılabilir. Mikro şebekeler farklı türden küçük yüklü topluluklara yüksek güç kalitesiyle kesintisiz enerji sağlayabilen ve tüketicilerin teknolojik tercihlerini, dolayısıyla enerji kalitesi talebini karşılayabilen küçük ölçekli enerji şebekeleridir. Dağıtım şebekesine enterkonekte haldeki ya da izole moddaki mikro şebeke sistemleri enerji kaynakları (mikro türbinler, yakıt hücreleri, güneş pili, vb), saklama cihazları (volantlar, enerji kapasitörleri ve bataryalar) ve yüklerde koordineli operasyon elde edebilir. Bu çalışmada, Türkiye'deki ve dünyadaki mikro şebeke potansiyeli, mikro şebeke sistemlerindeki teknolojik gelişme ve bu teknolojilerin Türkiye ve dünyadaki kullanım durumu değerlendirilmiştir. Mikro şebeke sistemlerine önem atfetmenin yenilenebilir enerji kullanımında artış sağladığı belirtilmiştir.

Anahtar kelimeler: mikro şebeke sistemleri, dağıtılmış enerji kaynakları, yenilenebilir enerji

I. INTRODUCTION

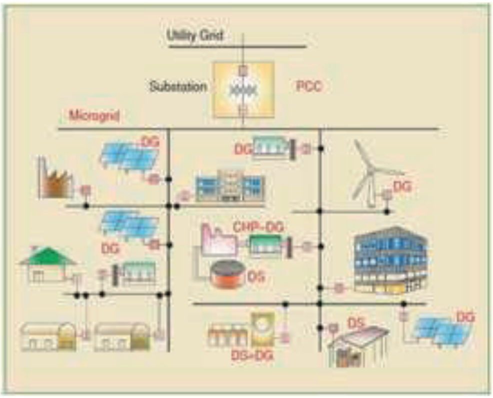
Recent developments in the electric utility industry are encouraging the entry of power generation and energy storage at the distribution level. Together, they are identified as distributed generation (DG) units. Several new technologies are being developed and marketed for distributed generation, with capacity ranges from a few kW to 100 MW.

The DG includes microturbines, fuel cells, photovoltaic systems, wind energy systems, diesel engines, and gas turbines [1, 2].

Traditionally, electric distribution networks have been used to deliver electricity to consumers [3]. Transmission and distribution of electricity over long distances has a great importance for economic and industrial development of a country. In recent years distributed electricity generation has been spread instead of central electricity generation. Satisfactory future development of various renewable energy sources (fuel cell, solar energy, wind energy, etc.) is the most important role on spreading of this trend.

When power systems are designing, organization of generation, transmission, distribution and sources is considered. In the near future, usage of distributed and various generation systems is expected instead of large central power generation stations and transmission through high voltage transmission lines for electric power generation and distribution in changing. In some new automation systems, number of consumers who can't get energy can be reduced by closing another circuit breaker to provide an alternative power flow way after faulty areas are identified.

Figure 1 – Alternative energy conversion technologies



As shown in Figure 1, DES systems include solar cells, wind turbines, mini-hydraulic generators, geothermal energy and fuel cells. Solar and fuel cells generates DC voltage. Also variable frequency alternative voltage is obtained from hydro and wind energy. Network integration is achieved by converting DC voltage through inverter and converting variable frequency alternative voltage. Batteries, ultra-capacitor, magnetic coil or generator, flywheel are used as storage systems.

Tablo 1 – Advantages and disadvantages of DES.

DES	
Advantage	**Disadvantage**
Modularity: Short duration of installation	Uncertainties in performance
Ability to meet market expectations	High cost
Fuel options	Inadequate standards
Improving power quality	Control problem about peak reduction
Reduction of transmission losses	Inadequate knowledge, planning and tools in operation
High efficiency	
Reliability	
Security	
Environmentally friendly (low and zero emissions)	
Possible load management	

As shown in Table 1, DES system has advantages as well disadvantages. Some requirements expected from DES system are voltage adjustment, synchronization, isolation, earthing, voltage or frequency disturbance response, disconnect from network in case of failure, voltage flicker, harmonics and turn to island mode [4].

II. MICROGRID SYSTEMS STATUS OF TURKEY

Distributed electricity generation in Turkey was began with law that paving the way to private electricity generation and has been accelerated with widespread use of natural gas [5]. In the second half of 1990s, many plants licensed auto producer natural gas operated has been opened in factories at Thrace, Sakarya, Ankara and Bursa regions.

As of Feb. 2014 in Turkey, total installed power of 284 DES is 2841 MW as 137 of these DES are auto producer licensed. This amount is 6.7% of the country's currently installed power. Shares of distributed generation plants and total generation plants based on renewable energy sources are shown in Figure 2. Accordingly to this, only 29.75% of distributed generation plants currently in operation are met from renewable sources. Largely natural gas and fuel oil fired plants are located in distributed generation systems.

Figure 2 – Rates of renewable energy and distributed energy source according to installed powers [6].

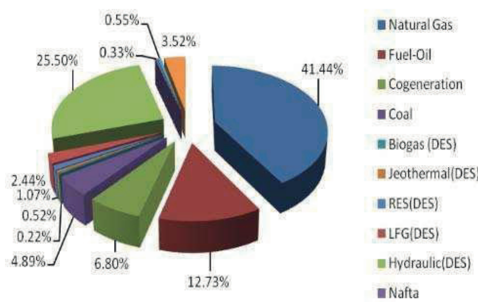


Table 2 – Numbers and powers of currently distributed energy plants in Turkey [6].

	Plant Type					
	Biogas		LFG		Wind	
	Number of plants	Power (MW)	Number of plants	Power (MW)	Number of plants	Power (MW)
Total (MW)	3	3	4	69.22	25	600.36
	Plant Type					
	Hydroulic		**Thermal**		**Total**	
	Number of plants	**Power (MW)**	**Number of plants**	**Power (MW)**	**Number of plants**	**Power (MW)**
Total (MW)	104	1012	100	1.614.70	290	3,141.92

As of Feb. 2014, numbers and powers of currently distributed generation plants in Turkey according to primary source are given in Table 2. Many medium-sized power plant is operated with fossil fuel, although there is significant amount of renewable energy sources in our country [6].

III. DEVELOPMENT OF MICROGRID SYSTEMS IN THE WORLD

A. *Europa*

Early microgrid RD3 in Europe occurred within the 5th Framework Programme (1998-2002). A Consortium led by the National Technical University of Athens (NTUA) included 14 partners from 7 EU countries, including utilities, e.g.Électricité de France, equipment manufacturers, e.g the German power electronics company SMA, and research institutions and universities, e.g. Labein. The main objectives were to study high renewable and other microsource penetration into the grid, microgrid islanding operation, and microgrid controls. Several levels of centralized and decentralized control were explored at several laboratories, notably the Institut für Solare Energieversorgungstechnik at the University of Kassel, the University of Manchester, and the National Technical University of Athens. A follow up project was completed within the 6th Framework Programme (2002-2006), again led by NTUA but with a somewhat different, although diverse, group of partners. This effort focused on new micro-sources, storage, and control. There was also considerable effort on network design, protocols, and the benefits and costs of µgrids (Hatziargyriou 2006). A new round of projects will soon begin under the 7th Framework[7,8].

Table 3 – Profile of the Kythnos Microgrid

Duration	Since 2003
Pilot Profile	-DG capacity el.22 kWp -DG Technology PV, battery, diesel-gen -Classification rural, off-grid
Tasks	-Microgrid operation -Multi master control method for improvement of available peak power and system reliability

As shown in Table 3, twelve houses in a small valley on Kythnos Island in the Cyclades Archipelago of Greece are supplied by a microgrid composed of 10 kW of PV, a 53 kWh battery bank, and a 5 kW diesel genset. The microgrid includes 3 SMA3.6 kW inverters connected in parallel to form one strong single-phase circuit in a master slave configuration.

A second demonstration has been conducted at the Continuon holiday camp in the Netherlands, which has more than 200 cottages equipped with a total of 315 kW of PV modules, interconnected by inverters.

The cottages are connected to a distribution transformer through four feeders, each about 400 m. Using a power electronic flexible AC distribution system and storage, islanded operation of the microgrid and power quality control will soon be tested. A third project in Germany, shown in Figure 4, at the 400-inhabitant Am Steinweg residential estate has 69 kW of DER including a 28 kW CHP plant, 35 kW of PV, and an 880 Ah battery bank. Other projects include an ecological estate in Mannheim-Wallstadt, as shown in Figure 4, and projects in Denmark, Portugal, Spain, and Italy. In addition to these EC projects, relevant European demonstrations are also being conducted at the national or local government levels [7,8].

Table 4 – Profile of the Mannheim-Wallstadt Microgrid

Duration	Since 2006	
Pilot Profile	-DG capasity el. -DG Technology -Classification -Grid Operator	Ca.22 kWp PV, CHP residential MVV Energie
Tasks	-Microgrid operation -Socio-Economic evaluation	

B. USA and North America

The Energy Independence and Security Act of 2007 (EISA) [8] defines the smart grid as "a modernizati on of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth". This law mandates federal and state agenci es to implement programs that help the development of the 'Smart Grid'. EISA states that simply adding mo re generators and transmission lines would not solve the energy needs of USA, but the existing grid infrastructure could be made more efficient by the use of intelligent systems, demand response strategies and new legislation that provide incentives for the efficient production, transport, and consumption of electricity [9]. This was corroborated by the National Electric Manufacturers Association (NEMA) and the Congressional Research Service[11,12].

Microgrids are both part and beneficiaries of the smart- grid concept. There are objectives shared between microgrids and the smart-grid concept: reduce the costs of energy and the reliability, efficiency and security improvement. Also, there are benefits which are linked to the use of smart-grid technologies: the deployment of green technologies, different levels of quality and the use of demand response strategies.

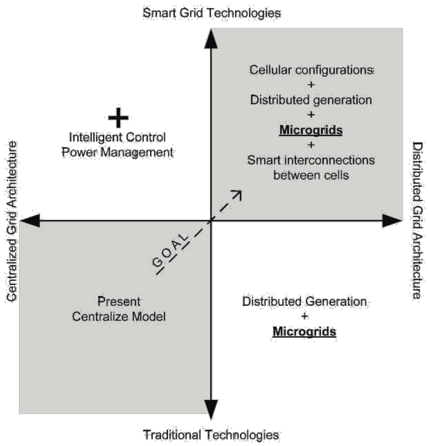


Figure 3 – Conceptual Framework of Smart Grid Alternatives. Adapted from [13]

Figure 3 show multiple links between microgrids and the smart-grid concept.

These link makes microgrid an essential part of the deployment and implementation of thee smart-grid concept in distribution networks. A recent US Department of Energy (DOE) market research estimates that microgrid will could supply between 1 GW to 13 GW of connected load by year 2020, which account more than 550 microgrids of an average capacity of 10 MW. However, for microgrids to capture this market it is necessary that they deliver the energy at favorable costs. Aside from better costs, microgrids could also deliver many different benefits and value propositions, thus the market size and public benefits can vary significantly depending in the conditions of the location. However, the same study estimates

that the "cost-reduction" value proportio n would generate 45 to 80% of the market, while the "reliability" and "green power" value proportions a re going to generate 25% of the market each[14].

C.Japan

Worldwide, microgrid RD3 is most active in Japan. To increase potential renewable energy harvesting near demand centers, Japan's microgrid RD3 focuses on utilising controllable prime movers, such as natural or biogas fired gensets, to compensate for variable demand and local small-scale intermittent renewable supply. The New Energy and Industrial Technology Development Organization (NEDO), the research funding arm of the Ministry of Economy, Trade and Industry, has started four demonstrations, in Funabashi and Yokoyama.

The first of Japan's µgrid demonstration projects started during the 2005 World Exposition, using a combination of varied chemistry fuel cells, 270 kW and 300 kW Molten Carbonate Fuel Cells (MCFC), four 200 kW Phosphoric Acid Fuel Cells, and a 25 kW Solid Oxide Fuel Cell (SOFC). The MCFCs use a gas derived from wood waste and plastic bottles. Experimental intentional islanding has also been conducted. Recently, the system was permanently moved to the Central Japan Airport City in Nagoya, where it will supply a Tokoname City office and a sewage treatment plant using a private feeder.

The Hachinohe, Aomori Prefecture, project began operation in October 2005 and is being evaluated for SQRA, cost effectiveness, and carbon emissions reduction over its demonstration period stretching through March 2008. The µgrid has PV and wind turbines totaling 100 kW, 510 kW of controllable engine gensets supplied by digester gas from a sewage plant, and a 100 kW lead-acid battery bank. Seven Hachinohe City buildings are supplied via a private 6 kV, 5.4 km distribution feeder, with the whole system connected to the commercial grid at a single point. Test islanding operation is also planned for this Project.

In a third NEDO project, the municipal government of Kyotango City, north of Kyoto, leads a virtual microgrid demonstration. The DER are included 50 kW each of PV and wind turbines, five 80 kW biogas engines, a 250 kW MCFC, and 100 kW of battery back-up. In this project, an energy centre communicates with the DER over the existing utility network to coordinate demand and supply. Imbalances between supply and demand are resolved within five minutes.

Finally, NEDO sponsors an ambitious and interesting multiple SQRA demonstration project in Sendai, Miyagi Prefecture. This microgrid demonstrates multiple SQRA on adjoining rest home, high school, university, and waste treatment facilities. The energy centre and a dedicated distribution line are connected at a single PCC. The main DER are a 250 kW MCFC, two 350 kW natural gas-fired gensets, 50 kW of PV, and batteries. The lead organization for this project is NTT Facilities, an arm of Japan's telecom giant. Because of this industry's expertise in the high SQRA DC systems that have always powered telephone service worldwide, the Sendai demonstration features direct service to DC telecom loads. As well as DC, multiple qualities of standard AC service are delivered from the clean power building marked in the rear of the compound, creating an outstanding example of heterogeneous SQRA. In fact, this microgrid supplies AC to the nearby buildings at four different service qualities. A premium quality A service for critical loads is never interrupted, and waveform correction is performed on it. When the utility grid has a momentary voltage sag or outage, the three B quality circuits receive SQRA. The B service is further subdivided into threedifferent types. During outages, the higher quality B1 service is backed up by storage, while B2 is backed up by distributed power, i.e. slower responding backup, while B3 service is not backed up and experiences grid SQRA (Hirose et al 2006). Note the similarity between this arrangement and the multiple SQRA on the various circuits of the CM.

In addition to the government-sponsored projects described above, there are significant research activities in Japan's private sector. Shimizu Corporation, a large construction company, is developing a microgrid control system at its Tokyo test facility. Also, Tokyo Gas, together with the University of Tokyo, plans to establish a µgrid to supply three-level power quality to a building of the Yokohama Research Institute[15].

IV. CONCLUSION

Microgrids are systems that can provide solutions for problems about electric power generation, network support and power quality. Installation of DES will be further accelerated by network support services offered by active power production. DES systems that can provide network support service with changes in their software are prone to develop with possibility of advanced energy storage systems will connect from outside.

Turkey has potential to use own solar and wind energy with high efficiency. The majority of our country's needs can be met by development of necessary power electronic interface for integration of fuel cells and renewable energy resources to distribution system should be taken into consideration. Taking place of distributed energy systems in electricity distribution systems in short time with support of various organizations and state is inevitable in the near future.

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