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COMBINED AC-DC MICROGRIDS: CASE STUDY - NETWORK DEVELOPMENT AND SIMULATION

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Abstract- The paper devoted to the developing of DG system on the base of hybrid AC/DC network. The attention paid to microgrids with hybrid power sources (wind, PV-solar, fuel cell, bio gas and so on) with ability to deliver electrical energy on twin power buses for further supplying of customers with AC and DC power. As an example micro grid with dc and ac power sources supplying parking area was investigated.

Keywords: Distributed Generation, Microgrid, DC Microgrid, Renewable Energy, PV Solar Unit.

I. INTRODUCTION

Traditionally electrical energy is generated on big power plants in close vicinity of fuel sources and then having been transferred to the centers of consumption. To reduce energy losses power transformers were used to increase voltage level till 220-1150 kV and then reduce it on the consumption side to the level of distribution network 35/10/0.4 kV. Such practice exists more than 100 years and considered the most effective. In regional distributive networks power flow usually directed to the one end - from substation to the customer. But until the recent time the distributive network (DN) as a part of the Grid considered as a passive due to absence of sources of electrical energy in it. Therefore, DN did not take part in power regulation. Situation didn't change even then some sources of renewable energy were introduced into circuit.

Application of RS (renewable sources) as well as other traditional sources of power in DN resulted in losses reduction and voltage profile improvement [1, 2]. But with deep penetration of RS into the grid it becomes inevitable to take them into account then analyzing steady state or dynamic processes in the energy system. It becomes available with advance technology devices for measurement and registration. Despite of the fact that future energy system would to rely mainly on central power plants as before, nevertheless it would use increasingly more RS, electrical energy storing devices, DG, electro mobiles, intellectual devices measuring energy, phase, censoring devices and communication equipment [9, 10].

In the contemporary period of time further improvement of energy efficiency and increased reliability may be reached by using the conception of smart grid or its first study – intellectual network [3]. This concept permit:
- to switch from radial supply circuit to circular, providing reliable connection of the end users with energy sources.
- to replace electromechanical system by digital providing necessary data needed by informational and automatic systems.
- provide two-way communication inside the energy system to create conditions for end users to switch from passive to the active participation on the energy market.

II. MICROGRIDS

The intellectual concept most easily may be realized in microgrids [4, 5]. In microgrid it is used the principle of micro generation by using sources and technologies of renewable energy to cover power demands of buildings, factories, schools, hospitals and even small population areas.

Technologies used in micro-grid involve: Solar thermal and PV-solar systems, wind generators, micro hydro power, fuel elements, biogas and combined heat and electricity production systems. For example:

- PV units convert solar energy to the electricity. This is favorable especially in the places there power consumption hours coincide with the period of the solar activity and also in the places there is no any power supply system.
- Wind generator converts wind energy to the electricity. Its application is more favorable in windy regions usually along seaside or in mountainous places.
- Combined heat production systems (CHP units) utilize heat extracted during fuel combustion at the thermal power plant. Despite of the fact that CHP units emit CO_2 improvement of their efficiency help to reduce emission of CO_2 comparing with remote power plant there heat as the sub-product is lost. CHP units gain advantage in the places there heat as sub-product may be effectively used.

- Biomass combustion use non-traditional fuel with emission of CO_2. Combustion chambers are rather big and frequent service is needed. This system is good where an adequate supply of biomass may be provided.
- Solar thermal panels are used for water heating. The most effective time to use them during sun shine, because it is rather difficult to keep water hot for a long period.
- In this connection novel idea of power supply for residential area, for example house or small object for commercial sector was studied. It is suggested to supply customers of the micro-grid from two buses. One bus has standard 10/0.4 kV AC voltage; the second one is DC bus 48V-400 V [1]. AC buses will supply rather powerful devices as air conditioner, refrigerator or washing machine. DC bus system may supply lighting system, consumer electronics and provide charging of electro mobile. Circuit of such micro-grid is presented on Figure 1. Among other advantages of the suggested arrangement is possibility to use energy of car batteries to supply DC and AC loads at the time of emergency.

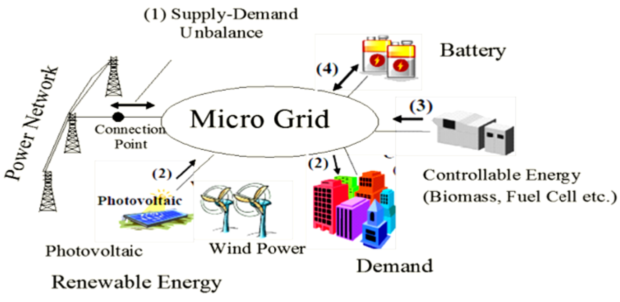

Figure 1. A hybrid microgrid

The idea to use dc power supply in distribution network was based on that:

- In the modern era of electronics most of the home and office appliances are operated from DC power, using different kind of transducers being connected to the standard 0.4 kV AC network. For example in some countries about 20% of consumed power is used for lighting and some 15% of total energy consumption is used by home electronics including computers. And all these end devices consume dc current [3].
- Application of distributed generation principle to improve reliability and efficiency of energy supply assume the creation of microgrid with renewable energy sources (wind generator, PV-solar unit, fuel cell and so on) which may supply customers with DC power.
- Output power of renewable sources has a random character so there are energy storage devices in microgrid-batteries, super-capacitor units, fly wheels and so on. Therefore there is always a reserve of dc current energy in micro grid.
- DC voltage may be used to charge batteries of electric cars and vice versa if necessary car batteries may provide micro grid by DC power.
- Using efficient converters and newest power electronics DC power may be easily and effectively converted to the ac power with different voltage level and necessity of transformers would fall away.

It is useful to add that because of existing central energy supply principle deviation of power quality and forced short-term outage of power supply just in the US industrial sector causes the annual loss of 120-190 billions of USD.

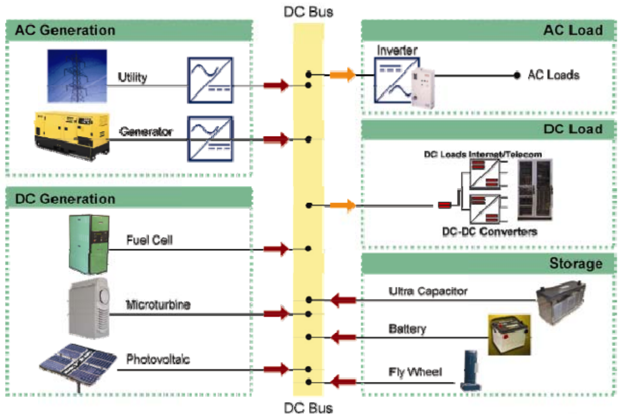

Figure 2. DC microgrid

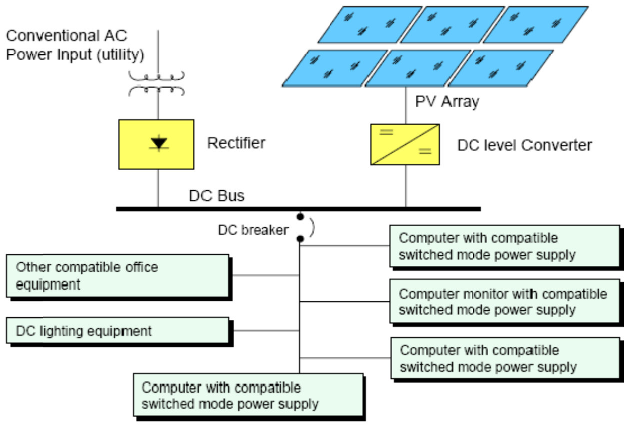

Figure 3. Power supply for office building

III. ADVANTAGES OF DC MICROGRIDS

- Not necessary the synchronization of DG networks generators;
- Deviation of generated and consumed power may be compensated in microgrids by installation of energy storage units;
- The loads are not impacted by harmonics, voltage sag or swell, non symmetry of phase voltages;
- Voltage quality does not change due to current surge (during commutation of induction containing circuits) or in presence of one phase load or generator;
- DC microgrids are more efficient than AC microgrids [6].

IV. DIRECTIONS OF FURTHER INVESTIGATIONS IN THE FIELD OF DC MICROGRIDS

The researches here may involve:

- HVDC systems to supply network with high voltage DC;
- Development of DC microgrid-distribution of DC current;
- Intellectual universal transformer-delivering DC energy to the customer;

- Development of system for the direct conversion of solar energy. Increasing viability of PV system;
- Consumer's portal. Installation of DC distribution box in every house;
- Electrical car connected to the microgrid-supplying the car with dc energy from network and vice versa E-car as a source of DC power.

V. BARRIERS ON THE WAY FOR WIDE RANGE REALIZATION OF DC MICROGRIDS

These are including:
- Fear of changing or fear of something new, non-traditional;
- Proved case of DC energy delivering still not clear;
- Most of the used equipment has no compatible input socket to feed from DC power supply;
- There are still no standards on safety and protection
- Standard practice on development, implementation and maintenance of DC microgrid is not mature;
- Still no standards in the level of voltages
- Induction machines with direct supply from AC terminals are the base of most industrial equipment [7].

VI. ON THE WAY TO DC MICROGRID: TRANSITION STAGE - A HYBRID AC-DC MICROGRID

On the first stage it is considered to use combined supply of consumers from DC and AC buses. Examples of such networks in Figures 4 to 7 were modeled and studied in ETAP.

As it is seen microgrid has connection with grid and get supply also from the 0.4 kV buses of diesel generator. There is an AC load connected to the same 0.4 kV buses. DC bus gets energy from PV solar unit. Both buses are connected with each other by two converters. To reduce power fluctuation of renewable energy sources there is power storage in the network-battery 1. E-cars are presented on model as Battery 2.

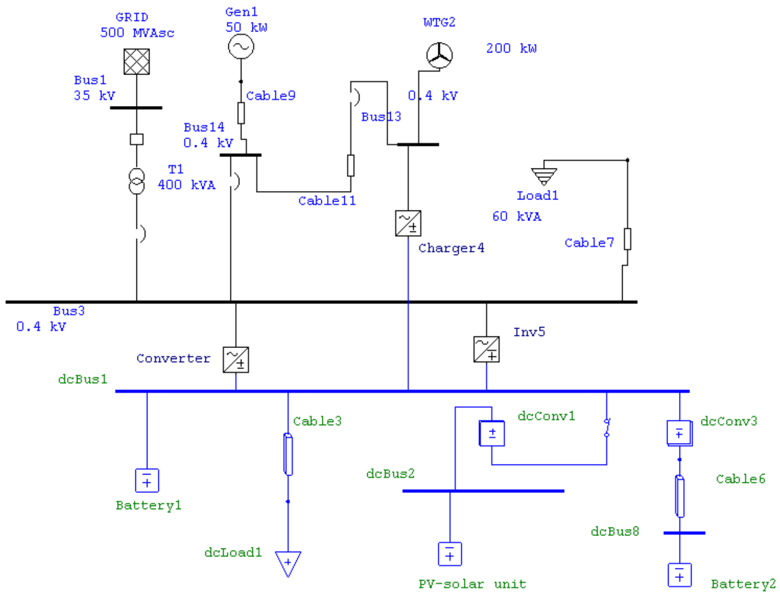

Figure 4. Model of analyzed AC-DC microgrid with wind generator

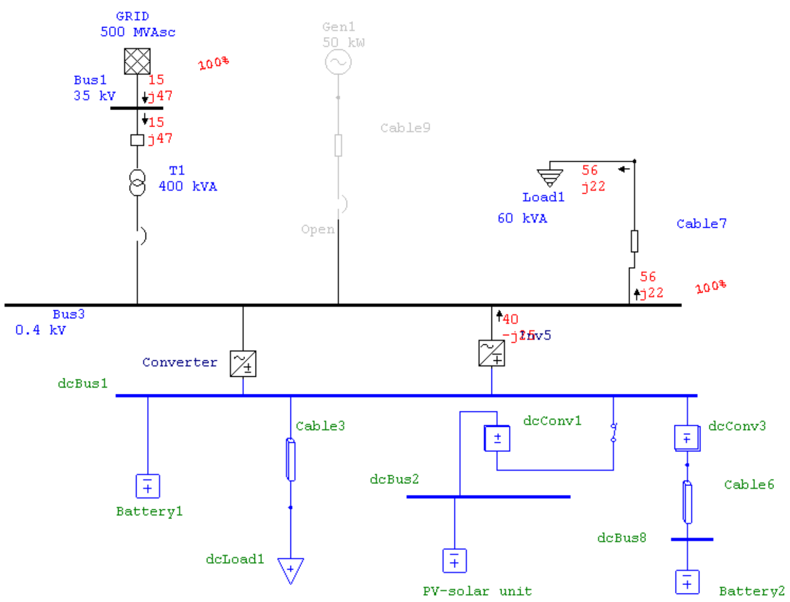

Figure 5. Model of analyzed AC-DC microgrid without wind generator

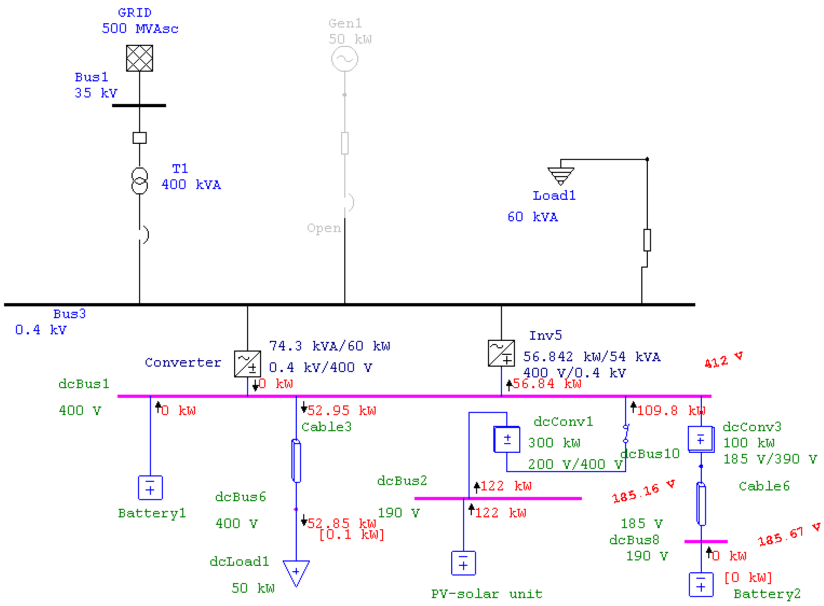

Figure 6. Hybrid DC-AC microgrid (LF of DC)

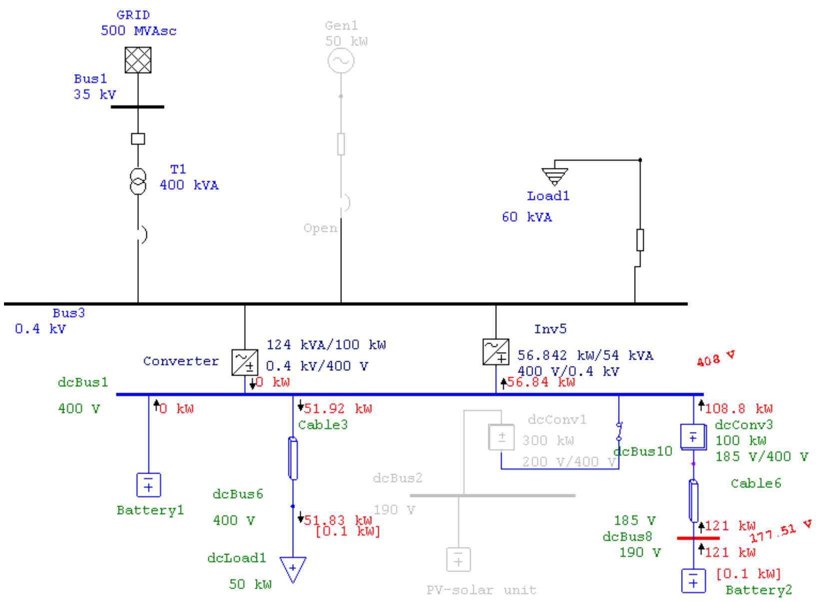

Figure 7. No power from AC bus and PV-unit (power entered into the microgrid from E-cars)

VII. CONCLUSIONS

Microgrids are the shortest way to realize the smart grid network.

- A Hybrid AC-DC microgrid can reduce the number of AC/DC or DC/AC converters in ac or dc microgrid [8].
- A Hybrid AC-DC power supply system concept may implemented on the base of micro-grid with further expansion to the cellular microgrid system.
- A Hybrid AC-DC power supply system increase energy efficiency and improve reliability.

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BIOGRAPHIES

Nariman R. Rahmanov received the M.Sc. and Ph.D. degrees from Azerbaijan State Oil and Chemistry Institute (Baku, Azerbaijan) in 1960 and 1968, respectively. He received the Doctor of Technical Sciences in Power Engineering from Novosibirsk Electro technical Institute, Russia in 1990. He is a Professor since 1990 and Director of Azerbaijan Scientific Research Institute of Energetic and Energy Design (Baku, Azerbaijan) from 2007 up to 2009, and Deputy Director of the same institute and SPII from 2009 up to present. He is Director of Azerbaijan-Norway Center of Cleaner Production and Energy Efficiency (CPEE Center). His research areas are power systems operation and control, distributed systems, alternative energy sources. His publications are more than 200 articles and patents, and also 3 monographs.

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Kamil Dursun was born in Ankara, Turkey, 1954. He received the M.Sc. and the Ph.D. degrees from The Norwegian Technical University, all in Power Electrical Engineering, in 1978 and 1984, respectively. He worked with ABB in several countries. Currently, he is an Associate Professor of Power Engineering at Ostfold University College (Fredrikstad, Norway). He is the secretary of International Conference of ICTPE. His research interests are in the area of efficient power distribution, energy management systems and virtual e-learning educational systems.

Oktay Z. Kerimov graduated from Azerbaijan Industrial Institute (Baku, Azerbaijan) as a Mechanical Engineer in Automation Control. He received Ph.D. degree from Moscow Institute of Power, Russia in 1970. He was Senior Researcher in Azerbaijan Institute of Power (Baku, Azerbaijan) from 1962 till 1981. He was a Visiting Scholar in UC Berkeley, Calif from 1977 till 1978. He also was an advisor on Power Systems in Park Holding, Turkey at the period of 1993-2004. At 2005 he joined again to Azerbaijan Institute of Power as the Head of Energy Saving and Efficiency Laboratory.