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INTEGRATED HYBRID MICROGRID - THE CELL OF FUTURE DISTRIBUTION NETWORK

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Abstract- Sustainable development of energy system is considered on a new basis by creation of distribution network in the form of microgrid containing distributed sources - renewable and traditional. In microgrids renewable sources as solar plants, wind mills, biogas units, energy accumulation units and some others are used in combination with such traditional power sources as diesel generators, small gas turbines. Rated power of microgrid sources is designed to cover local demand. The studied combined microgrid has connected to the main grid. Taking in consideration the high price of power conversion equipment the efforts were made to minimize their number. Modeling of combined microgrid, results of steady state evaluation and analysis in different operation conditions are considered.

Keywords: Distributed Generation, Microgrid, Renewable Energy Sources, AC/DC Network of Energy.

I. INTRODUCTION

Distribution network (DN) is a base of any Energy system until recent time considered as a passive network with power flow direction from utility transformers to the load. Later on with development of distributed generation concept and with involvement of renewable energy sources in the network situation slightly changed. Application of RES (renewable energy 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 RES into the grid it becomes inevitable to take them into account then analyzing steady state or dynamic processes in the energy system. In modern energy system it becomes available with used advance technology devices for measurement and registration.

Considering that future energy system would rely mainly on central power plants as before, nevertheless it would use increasingly more RES, electrical energy storing devices, DG, electro mobiles, intellectual devices measuring energy, phase, censoring devices and communication equipment. In addition, further improvement of energy efficiency and increased reliability may be reached by using smart grid technology for power system control [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.

It is planned to increase in nearest future the share of renewable energy till 10-15% [4]. This can be done in two ways:

By construction of big wind farms and solar power plants on the rather big allocated territory which is situated relatively far from the consumption centers. To deliver energy to those consumers it is necessary to build a huge transmission line which is rather expensive. Construction of the 100km overhead power line with power flow capacity 800MW for example cost about 1mlrd USD [4]. And we have to remind that about 5-10% of transmitted energy would be lost in transmission chain;

The second way is a creation of microgrids i.e. further developing of distribution network with inclusion of renewable energy sources and making changes in measuring and control infrastructure with help of smart devices and equipment. In this case it is offered to place PV solar panels on the houses roof, to use fuel cells, energy storing devices - batteries and so on.

II. MICROGRID

Microgrid is a small option of modern centralized power system. It served to customers supplying them with electrical power increasing the reliability of power supply, reducing pollution of environment, providing diversification of energy sources and saving finances. Just as a Main Grid, microgrid has to generate, distribute and control energy flow to customers but curries out it on the local level [5, 6, 7]. Intellectual microgrid is the ideal way to unite renewables on the regional level which create a possibility for customers to take part in generation and distribution of electrical energy.

Microgrid is a building brick of the perfect energy system. One of the important advantages of the microgrid is the ability to give an opportunity to customers a chance to make the intellectual decision in the way of using electrical power. If there is a need, microgrid could buy energy from the grid, but at the time of increased price may be separated from a grid and work in islanded mode. Microgrids provide not only energy source optimization but also power consumption. Good designed microgrid could withstand fault in the network not only by de-energization of a whole network or the part of it but also by selective switch-off of respective feeders. Another advantage of the onsite generation is the optimal use of thermal energy. To the contrary in the big thermal plants there about 60-80% of used energy does not transform to electricity, at microgrid this energy may be used in regional format.

As a first stage to realize microgrid concept a combined AC/DC network is analyzed in this paper. The combined microgrid was chosen because of the development and deployment of renewable energy sources with dc output power and increasing number of end loads, which are using dc currents. Energy management, control and operation of a combined microgrid are rather difficult therefore we would investigate some operating modes of it. Uncertainty and intermittent character of generated energy force the design engineers to develop special control system for hybrid microgrid [8, 9, 10]. We study different operating modes of a combined microgrid.

III. NETWORK CONFIGURATION AND MODELING

The pilot project for investigated network was constructed on the hillside of small town and has 3 wind generator units with nominal power 1MW each, PV solar power unit producing 0.5 MW and controllable Biomass energy unit with capacity 0.5 MW (Figure 1, [13]). A combined microgrid was modeled using certified software [11] (Figure 2). The studied circuit has two system buses - AC bus 5 and DC bus 6. AC bus is loaded by 600 kVA static Load 2 and DC bus 6 is loaded with static 200 kVA Load 1. Static load at DC bus is mostly lighting load.

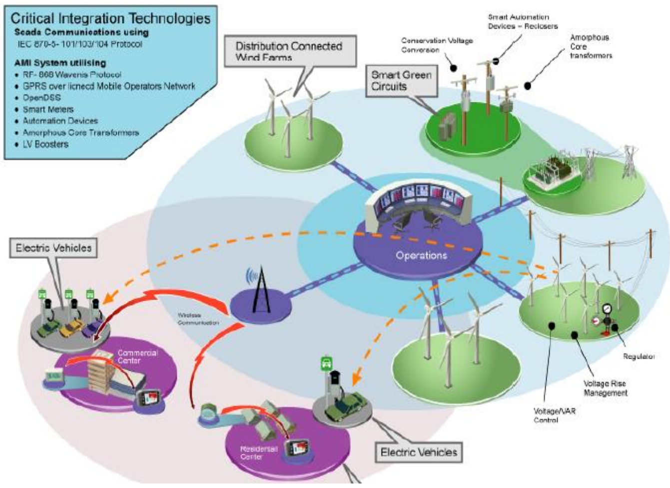

Figure 1. A simplified circuit of microgrid

AC buses are supplied from wind farm 3×970 kW and Diesel generator (Gen. 1) with rated power 500 kW (Figure 2). DC bus 6 is connected with 500 kW PV solar power station, energy storing device (Battery 1) and commercial parking lot with PEV charging appliances. Steady state evaluation in the studied network is made for two cases:

- Case study 1: microgrid is operating in parallel with grid.
- Case study 2: microgrid is operating in islanded mode.

As it is seen from Figure 2 along with traditional diesel generator Gen. 1 there is a small wind farm WG1 with three power units (3×970k W) supplying static 600 kVA Load 2 through AC bus 5. Output of PV solar unit 200 V is connected through DC/DC transformer (level multiplier 400 V) with DC bus 6.

This bus also is connected with energy storing device (Battery 1), Load1 and Terminal (Bus9) for commercial parking lot with PEV and PHEV charging appliances. Both system buses are connected with each other by two converters and isolation transformers to provide energy exchange between AC and DC networks.

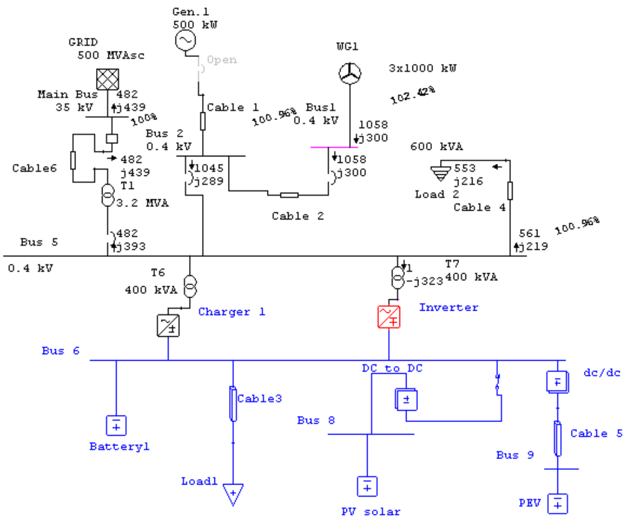

Figure 2. Combined microgrid (parallel operation, Gen. 1 is off, wind speed 10 m/s), AC side load flow

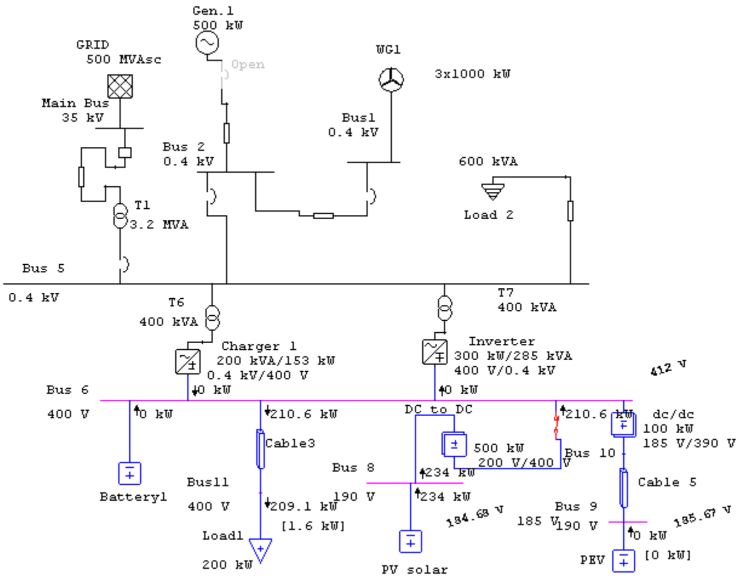

Figure 3. Combined microgrid (parallel operation, Gen. 1 is off, wind speed 10 m/s), DC side load flow

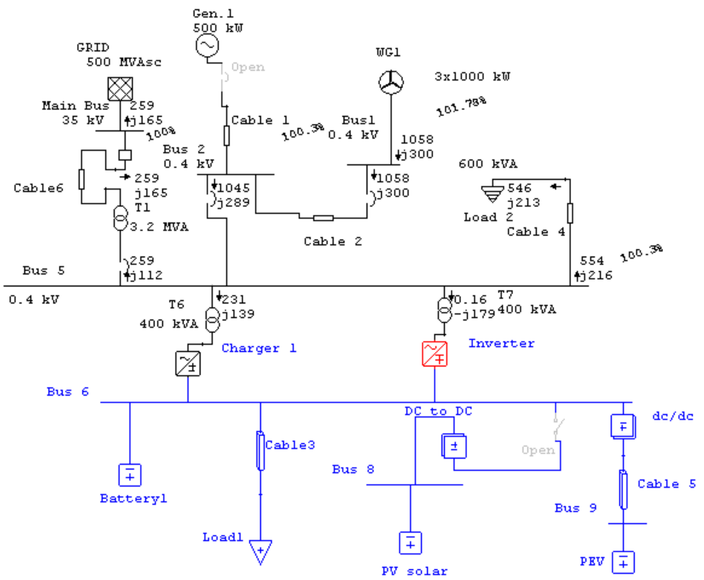

Figure 4. Combined microgrid (parallel operation, Gen. 1 and PV solar unit are off, wind speed 10 m/s), AC side load flow

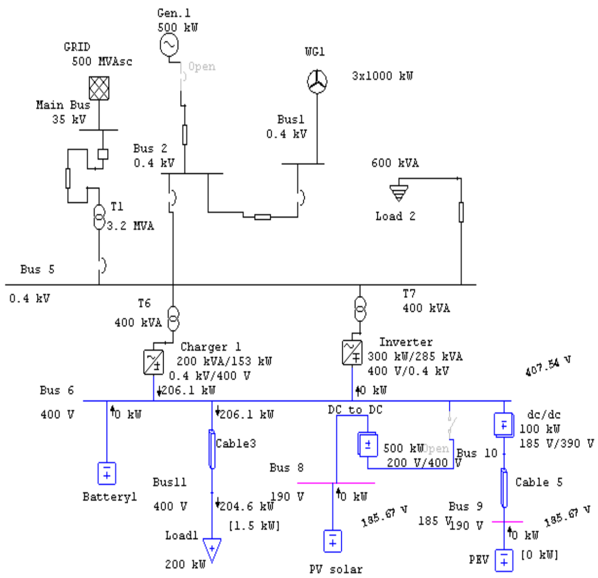

Figure 5. Combined microgrid (parallel operation, Gen. 1 and PV solar unit are off, wind speed 10 m/s), DC side load flow

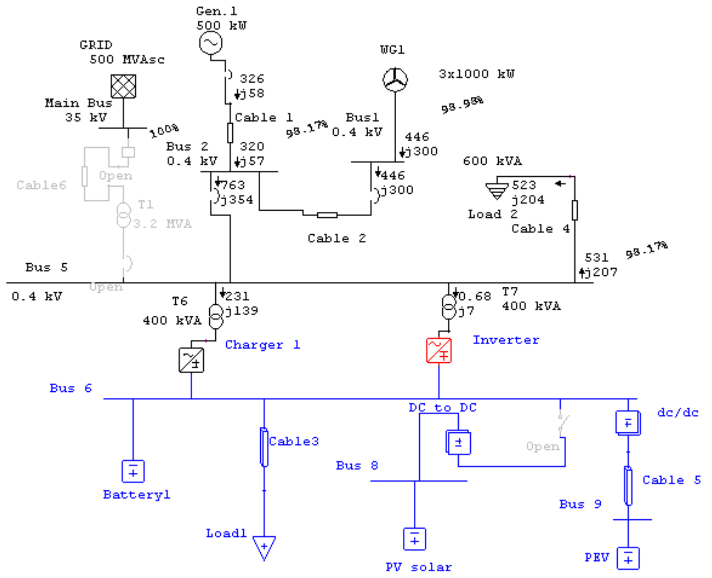

Figure 6. Combined microgrid (islanded operation, PV solar unit is off, wind speed 7.5 m/s), AC side load flow

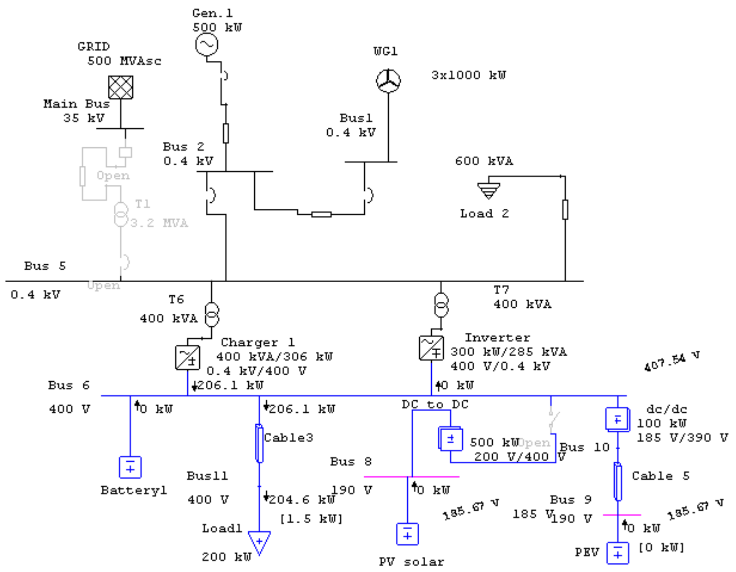

Figure 7. Combined microgrid (islanded operation, PV solar unit is off, wind speed 7.5 m/s), DC side load flow

In the Case 1 study (Figure 2) RES units are operating in parallel with Grid. Normally we desire first of all to use wind and PV solar energy sources as environmentally more cleanly than others and consider that Gen. 1 is out of operation. We have to check if the power generated by RES could cover demands of all end users in combined network. As it follows wind farm in this case produces more energy than AC network connected Load 2 nominal power. So as it is seen from the load flow results some extra produced power (482 kW) is transferred to the Grid. At the DC network power produced by PV solar plant meets the Load1 demand and there is no power exchange between the AC and DC buses.

DC load flow for the Case1 study is introduced on Figure3. On the Figure 4 PV solar plant does not produced power (night time) and excess power supplied by wind farm through the Charger 1 (231 kW) meets the demand of DC network and some part of power (259 kW) from wind farm does flow to the grid. DC load flow for this case is shown in Figure 5.

Islanded operation of studied hybrid network (Case 2) is introduced on Figure 6. The hybrid network is separated from the Grid (connection tie -Cable6 is switched off), PV solar plant produces no power and wind farm WG1 produces less power (446 kW) than before because of low wind speed 7.5 m/s. But in this case diesel-generator Gen1 put in action providing needed 231 kW and together with WG1 meets the demand of AC side and simultaneously through the Charger1 supplies Load 1 with DC power. Load flow for DC network is shown on Figure 7. The main results of all case studies collected in Table 1.

So energy flow and power exchange in studied hybrid microgrid system depends on working parameters of elements forming the system. The approach considered in this paper provides less number of used conversion elements [12].

Table 1. The main results of all case studies

Mode of operation	Power flow from grid or (diesel) kW + kVAR	Power flow to the grid	Power flow from AC to DC bus
parallel operation, Gen. 1 is off, wind speed 10 m/s	0	482 + j439	
parallel operation, Gen.1 and PV solar unit are off, wind speed 10 m/s	0	259 + j165	231
islanded operation, PV solar unit is off, wind speed 7.5 m/s	326 + j58		231

IV. CONCLUSIONS

The main contribution of this study is evaluation of the microgrid structure and operation that aims advance using of power produced by RES and on the other hand decreasing their impact on grid. Parallel and islanded operation of combined microgrid with Grid for some different modes of operation modeled in ETAP software did prove normal steady operation of studied microgrid circuitry with ac and dc elements. Just two conversion elements are enough to provide energy exchange between two energy buses. PV solar panels could contain no built in inverter elements. In used PV solar units it is recommended to apply models without built in inverters so the hybrid microgrid has an advantage to use a minimal number of conversion devices.

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BIOGRAPHIES

Arif M. Hashimov was born in Shahbuz, Nakhchivan, Azerbaijan on September 28, 1949. He is a Professor of Power Engineering (1993); Chief Editor of Scientific Journal of "Power Engineering Problems" from 2000; Director of Institute of Physics of Azerbaijan National Academy of Sciences (Baku, Azerbaijan) from 2002 up to 2009; and Academician and the First Vice-President of Azerbaijan National Academy of Sciences from 2007 up to 2013. He is laureate of Azerbaijan State Prize (1978); Honored Scientist of Azerbaijan (2005); Cochairman of International Conferences on "Technical and Physical Problems of Power Engineering" (ICTPE) and Editor in Chief of International Journal on "Technical and Physical Problems of Engineering" (IJTPE). His research areas are theory of non-linear electrical chains with distributed parameters, neutral earthing and ferroresonant processes, alternative energy sources, high voltage physics and techniques, electrical physics. His publications are 280 articles/patents and 5 monographs.

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 Research Institute of Energetics 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.

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, CA, USA 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.