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SIMULATION OF STEADY STATE OPERATION FOR AC/DC MICROGRID

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Abstract- This paper presents hybrid AC/DC microgrid with different power value of conventional and renewable energy sources and defines reaction of network in normal steady state and transient state condition. AC part of network has an AC collector bus with connection of wind generator and conventional diesel generator. This part of network has connection with main Grid. DC part of the network has a DC collector bus with connected PV-solar units, storage batteries. Both AC and DC buses have AC and DC loads respectively. On the other hand AC and DC buses are connected through bidirectional energy conversion units. Power flow analysis for various state of the network is performed taking in account presence or absence of connection with Grid and for various level of power production by wind and PV-solar units. In transient state caused by disturbances in Grid the power exchange between microgrid and Grid as well as power exchange between AC and DC buses were studied.

Keywords: Microgrid, Wind Generator, PV-Solar Unit, AC/DC Networks.

I. INTRODUCTION

Recently local networks with small power DG systems to supply residential or office building and municipal or farm units are in the progress. Such networks are preferable for island operation to supply with on site generation internal loads but may also have power connection with the main electrical system. The technology used in such microgrids is small wind generators, PV solar panel systems, micro hydro units, fuel cells, CHP units and some others [1-3]. 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 required, the 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 on- site generation is the optimal use of thermal energy. On the contrary the big thermal plants does not transform to the electricity about 60-80% of used energy. At the microgrid this energy may be used in regional areas [4, 5].

To use microgrid effectively, it is required to simulate and analyze the operation modes of combined AC/DC network. There are a few researches in this field [6-8]. Combined microgrid was chosen because of the development and deployment of renewable energy sources with DC output power and increasing number of end- users, 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. Operation of microgrid is studied under different output power levels generated by renewable sources. It is defined here what combination of renewable and conventional energy sources meets consumption in microgrid. For every operation case power flow between both AC and DC buses is defined. Dynamic stability due to failure in external system is studied. Reaction of rotating micro-sources (diesel generator and wind generator) and time necessary for system normal operation condition after fault clearance is analyzed.

II. NETWORK CONFIGURATION AND MODELING

To provide convenience in comparing results researching various cases of network operation with different combination of renewable and conventional sources and provision of easy connection for DC consumers to the DC collector bus the typical circuit Figure 1 was designed.

The studied circuit in Figure 1 has two system buses – AC bus 6 and DC bus 7. AC bus is loaded by 80 kVA lump load1b, 60 kVA static Load1a and DC bus 6 is loaded with static 50 kW Load2. Static load at DC bus is mostly lighting load. AC buses are supplied from wind unit 200 kW and Diesel generator (DG-1) with rated power 70 kW (Figure 1).

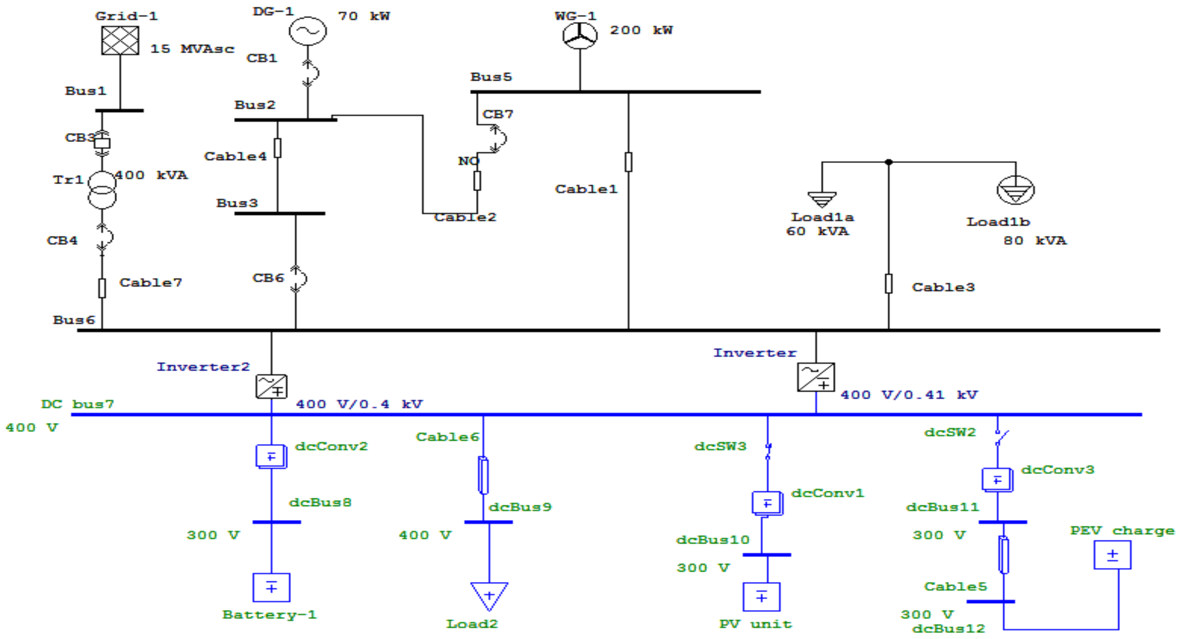

Figure 1. Model of microgrid network

DC bus 7 is connected with 200 kW PV solar power station, energy storing device (Battery 1) and commercial parking lot with PEV (plug-in electrical vehicles) charging appliances.

Steady-state evaluation in the studied network is made for two cases:

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

Simulation models of AC sources- wind turbine (DFIG), and DC sources as PV-unit, Batteries are known and described in bibliography [11, 12, 13]. All models are simulated using ETAP 6 software [14].

III. CASE 1: PARALLEL OPERATION

In Figures 2(a)-2(b), it is presented the case then DG-1 is switched off (no fuel, for example) and WG-1 does not produce power (wind speed is lower than 3 m/s). PV-unit is producing much power (solar irradiation is high - 90%). Both inverters provide AC bus with total 99 kW of power (10kW are losses in inverters) and AC part of network is using the power generated on DC site plus some 29 kW purchasing from the Grid.

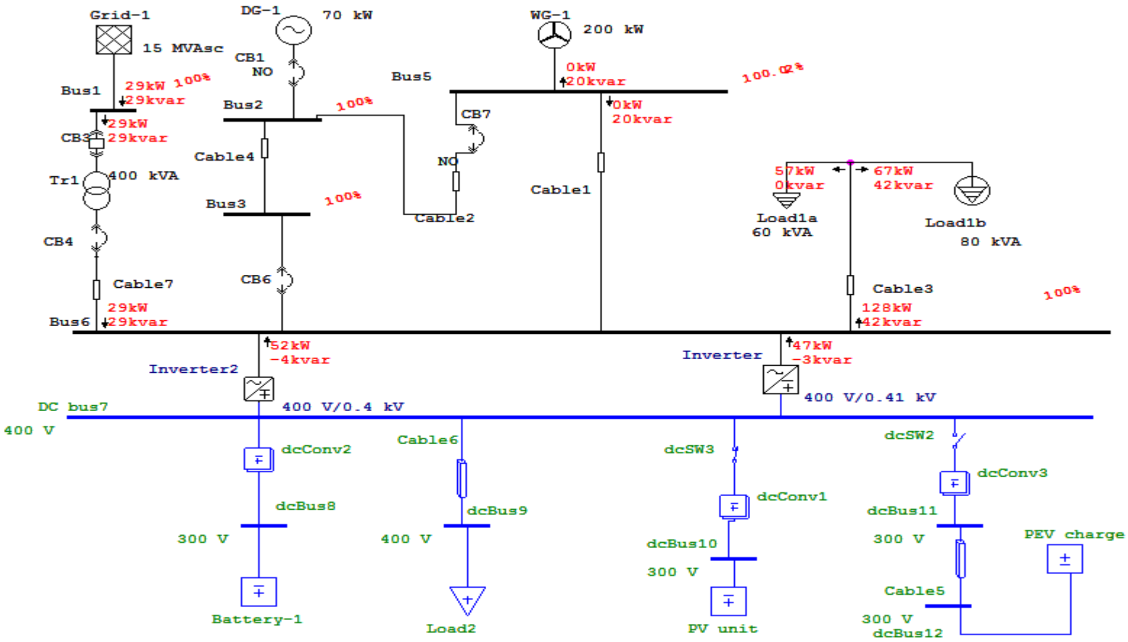

Figure 2(a). Parallel operation, LF on AC part of microgrid, Wind speed < 3 m/s

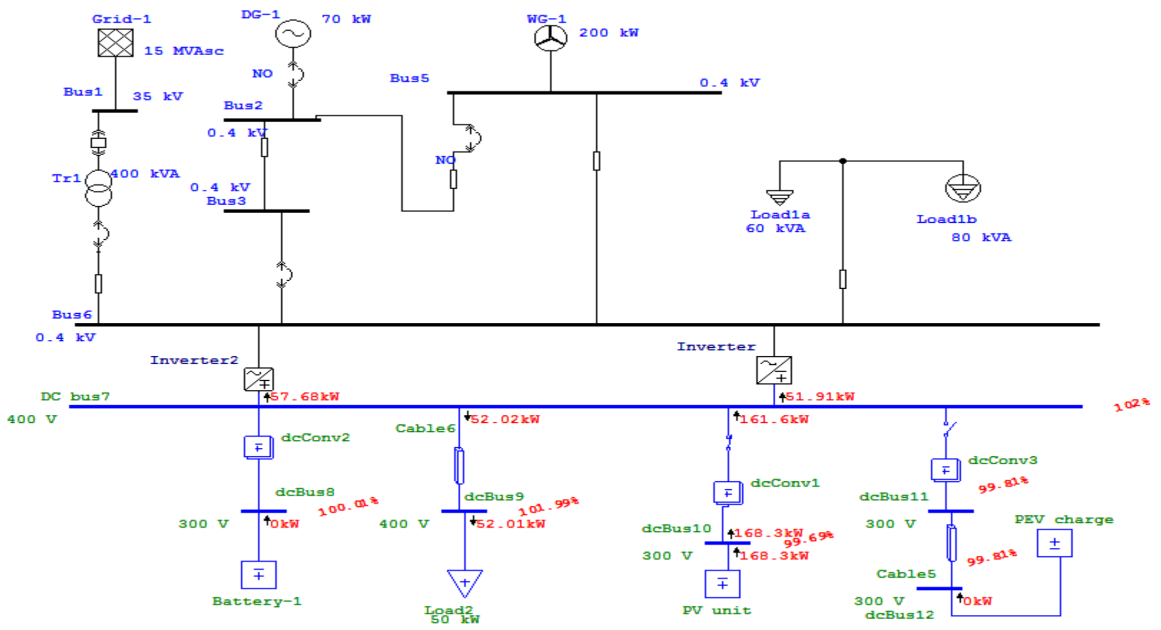

Figure 2(b). Parallel operation, LF on DC part of the microgrid, Wind speed < 3 m/s

In Figures 3(a)-3(b) it is presented parallel operation of studied micrigrid with wind speed 4 m/s. In this case WG-1 does produce 48 kW of power for AC network with wind speed of 4 m/s. Additional power 51 kW are from DC-bus through inverters and the remaining power for AC load is provided by Grid (29 kW). PV unit is capable to produce only 108 kW (solar irradiation low-50%). 52 kW are for local DC load and 56 kW for AC network.

In Figures 4(a)-4(b), it is the case then wind speed is 10 m/s. Power delivered into the AC bus is 94 kW and DG-1 is also in operation. Extra power in AC part of the network 30 kW is sold to the Grid. At DC part of microgid PV-unit is off (night time, for example), but DC load gets power from Batteries through DC converter dcConv2 (Figure 4(b)).

Another case of parallel operation with wind speed 12 m/s and opened DG-1 is presented in Figures 5(a)-5(b). WG-1 is producing 162 kW. 128 kW meets internal AC load demand and 30 kW is sold to the Grid. On DC part of microgrid PV-unit produces only 54 kW to provide energy demand of local DC load.

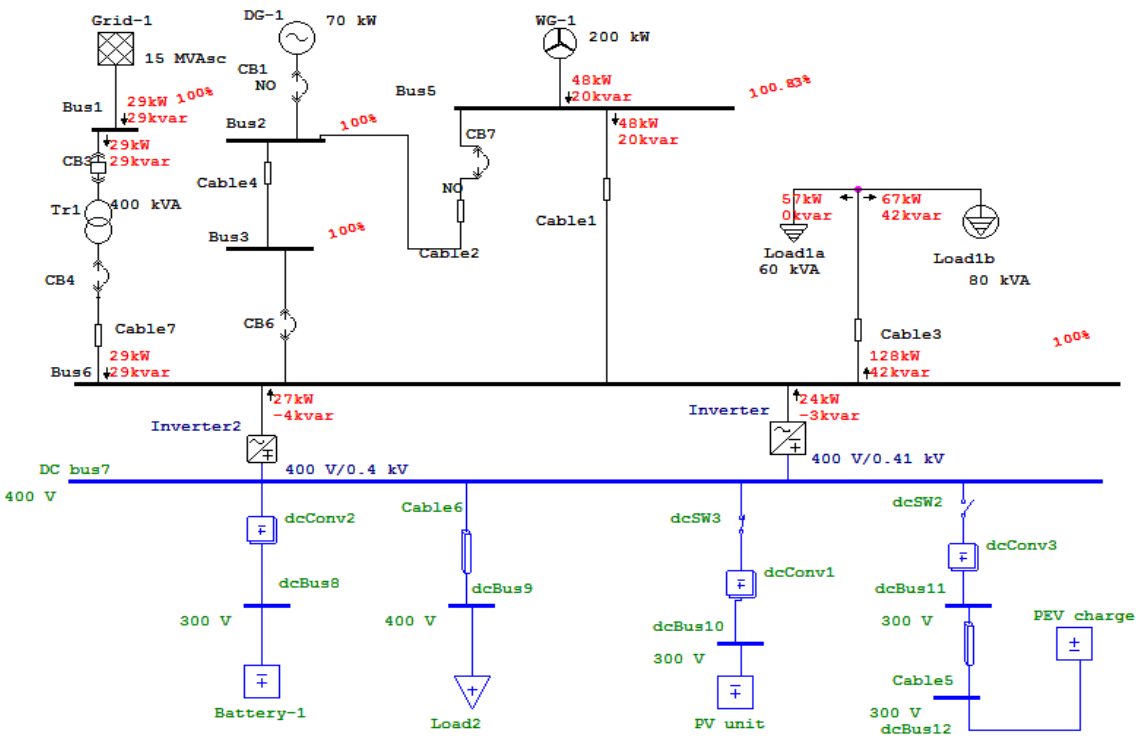

Figure 3(a). Parallel operation, LF on AC part of microgrid, Wind speed = 4 m/s

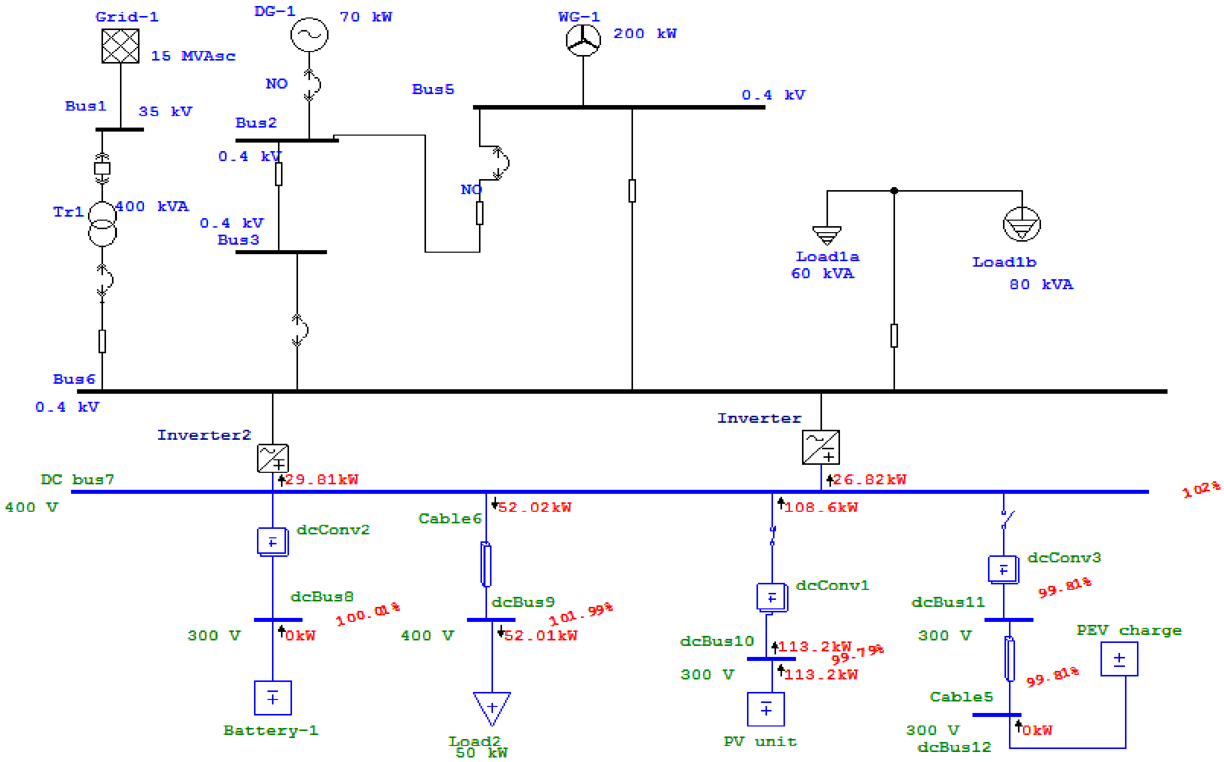

Figure 3(b). Parallel operation, LF on DC network, Wind speed = 4 m/s

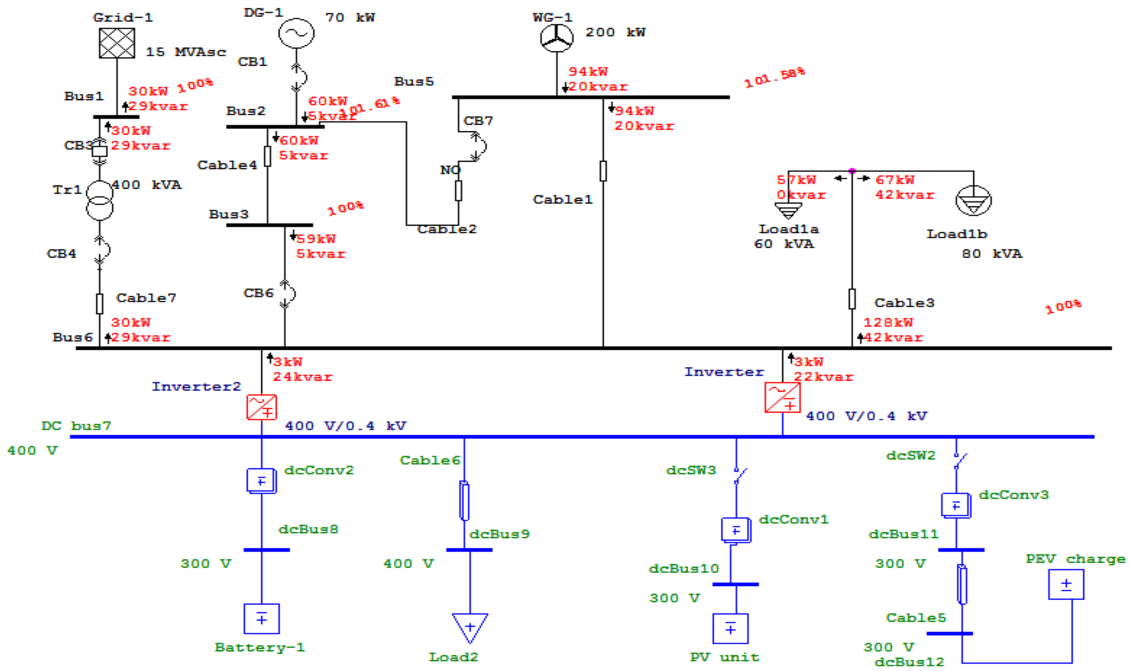

Figure 4(a). Parallel operation, Wind speed = 10 m/s - Load flow on AC network

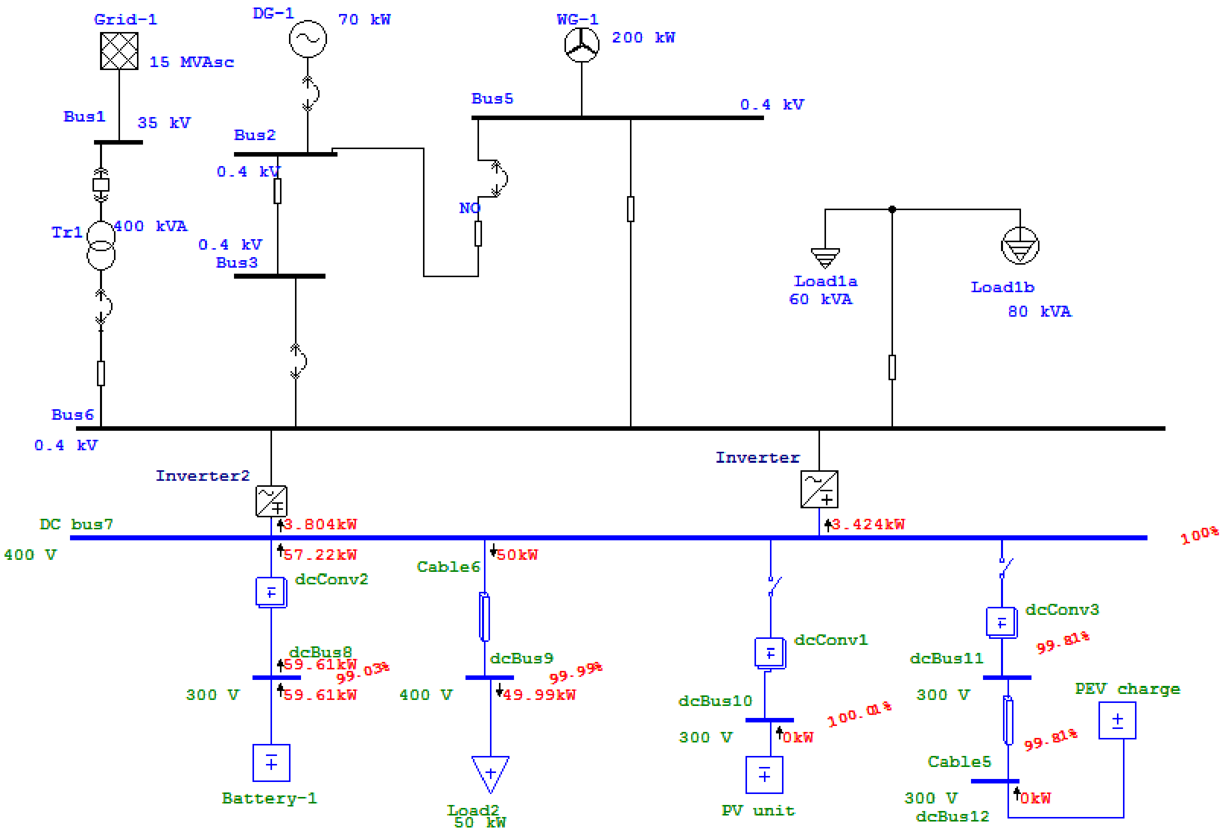

Figure 4(b). Parallel operation, Wind speed = 10 m/s - Load flow on DC network

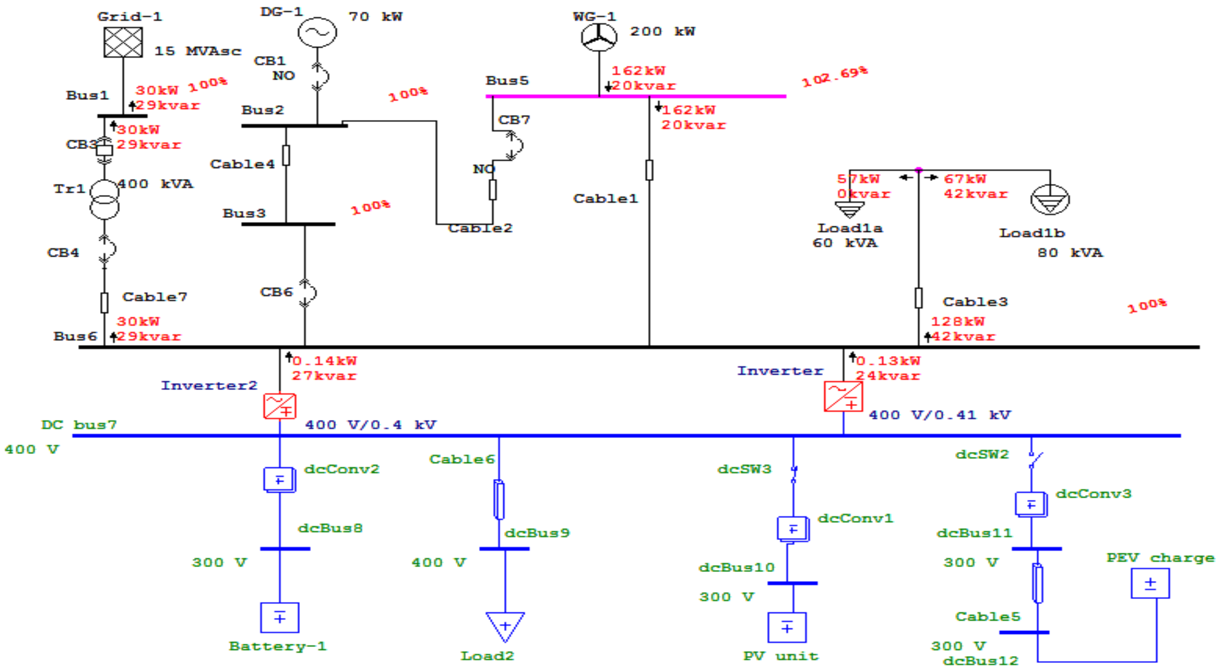

Figure 5(a). Parallel operation, Wind speed = 12 m/s - Load flow on AC network

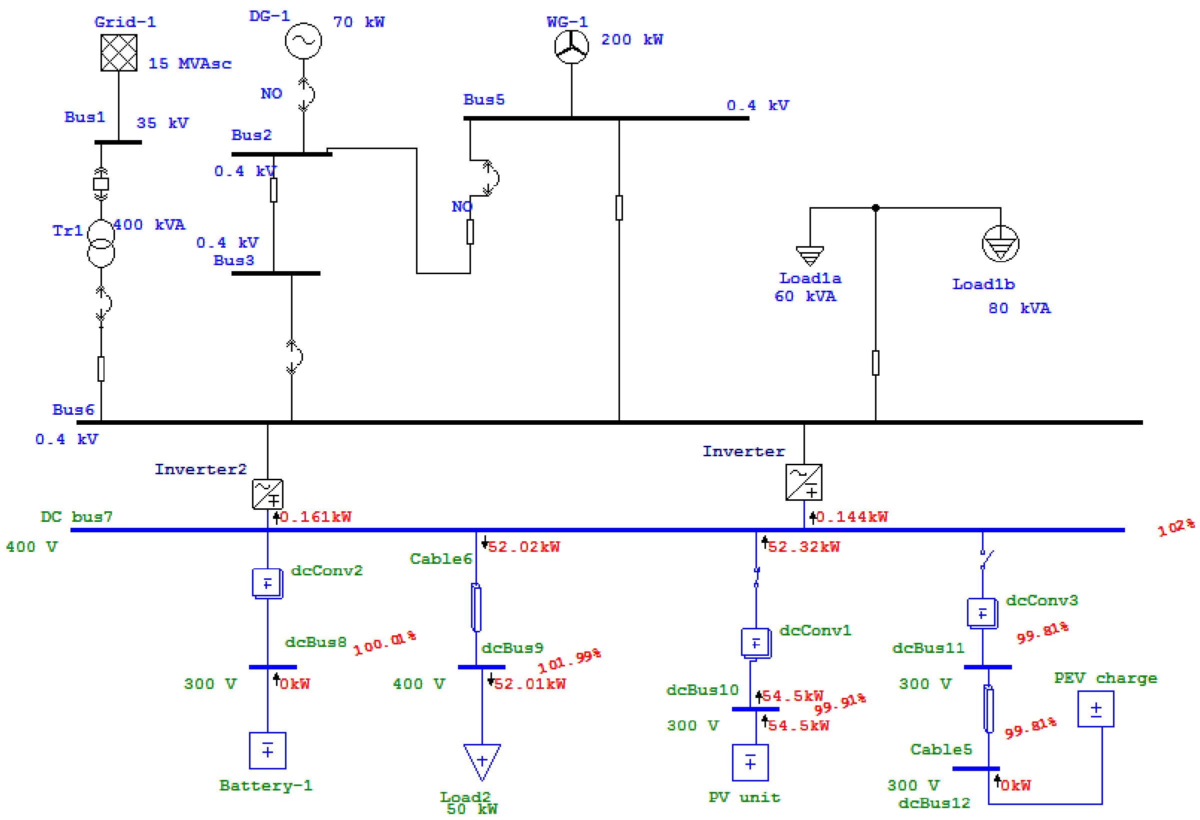

Figure 5(b). Parallel operation, Wind speed = 10 m/s - Load flow on DC network

IV. CASE 2: ISLANDED OPERATION

If for some reason microgrid lost connection with main Grid this regime is called as islanded. Normally lost connection with Grid is not preferable operation for microgrid, but if it happens the microgrid has to activate all internal sources including storage batteries to supply loads on AC and DC buses.

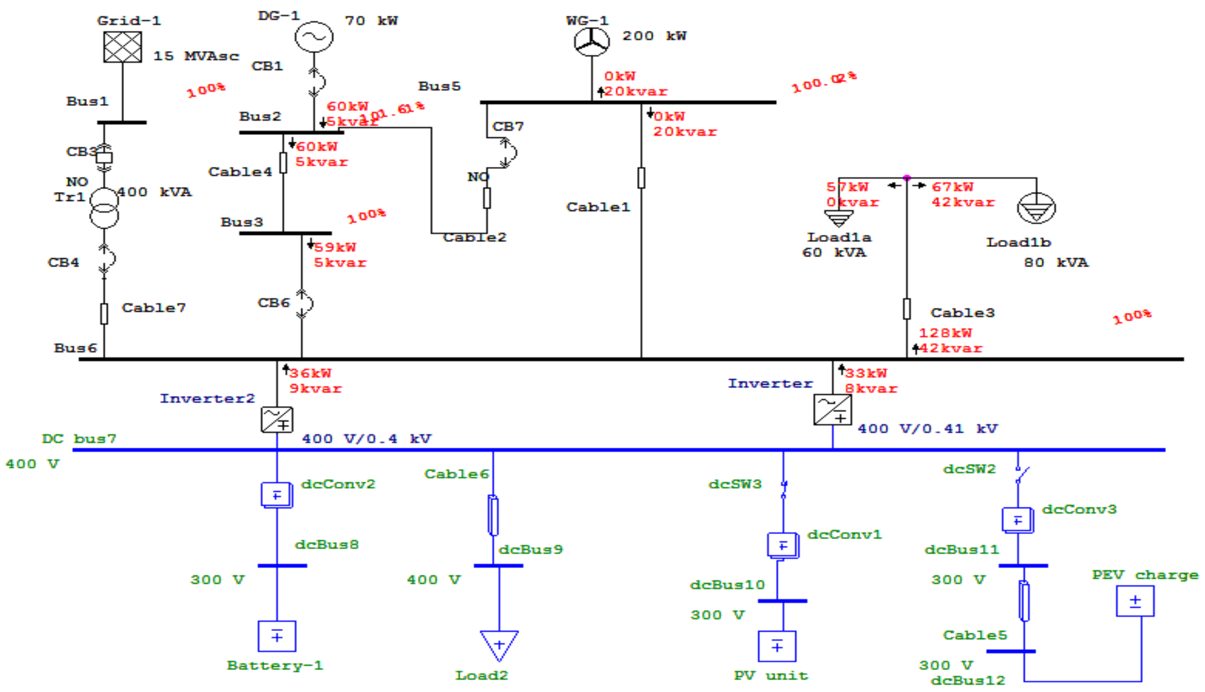

Figure 6(a). Islanded operation, LF on AC part of the network

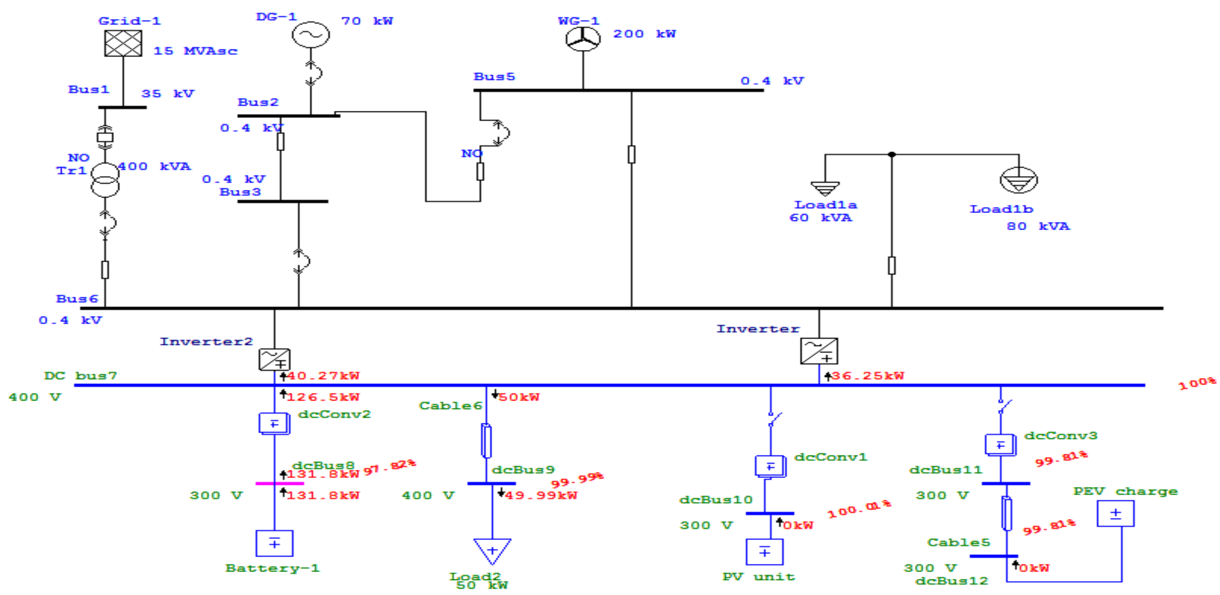

Figure 6(b). Islanded operation, LF on DC part of the network

One of the worst case is considered with no wind and no PV operation. Power is provided for AC load by diesel generator (60 kW) and partly from DC bus (69 kW) through inverters which is fed by batteries. As it seen in Figure 6, the grid separated by CB3 circuit breaker, WG-1 produces 0 kW because wind velocity is lower than 3 m/s. In addition to 60 kW generated by DG-1 the remaining 69kW for AC load is provided by DC bus through inverter. Results of study for steady state regime collected in Table 1.

Table 1. Results of study for steady state regime

Weather		AC sources power		DC sources power		AC load	DC load	Interconnection power flow Grid-Microgrid	Power flow exchange AC-DC
Wind speed m/s	Solar irradiation in % of I_{max}	Wind	Diesel	PV kW	Batteries				
0	90%	0	0	168	0	128	52	+29	109
3	90%	0	0	168	0	128	52	+29 (from Grid)	109
4	50%	48	0	113	0	128	52	29	56
10	0%	94	60	0	59	128	50	-30	7
12	0%	162	0	54	0	128	50	-30	0
The worst case, transient study, pre-fault conditions	22%	94	60	61	0	128	50	-30 (to Grid)	6

V. CONCLUSIONS

- The main contribution of this study is development of the hybrid microgrid structure with separation of sources producing alternative current with their loads from sources which traditionally produces direct current together with loads consuming direct current.
- Voltage control on appropriate level on the AC and DC buses as well as energy exchange between them is provided by control of AC/DC inverters and DC/DC converters which depends of output production of wind generator and PV-unit.

Parallel and islanded operation of modeled combined microgrid with Grid for some different modes of operation 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.

REFERENCES

[1] R.H. Lasseter, P. Paigi, "Microgrid: A conceptual Solution", IEEE 35th PESC, Vol. 6, pp. 4285-4290, June 2004.

[2] N.R. Rahmanov, N.M. Tabatabaei, K. Dursun, O.Z. Kerimov, "Combined AC-DC Microgrids: Case Study - Network Development and Simulation", 8th International Conference on "Technical and Physical Problems of Power Engineering" (ICTPE-2012), pp. 8-12, Fredrikstad, Norway, 5-7 September 2012.

[3] A.M. Hashimov, N.R. Rahmanov, O.Z. Kerimov, "Integrated Hybrid Microgrid - The Cell of Future Distribution Network", 9th International Conference on "Technical and Physical Problems of Electrical Engineering" (ICTPE-2013), Istanbul, Turkey, pp. 1-5, 9-11 September 2012.
[4] R. Noroozian, M. Abedi, G. Gharehpetian, "Combined Operation of AC and DC Distribution System with Distributed Generation Units", Journal of Electrical Engineering, Vol. 61, No. 4, pp. 193-204, 2010.
[5] R.H. Lasseter, "Microgrids", EEE Power Eng. Soc. Winter Meeting, Vol. 1, pp. 305-308, January 2002.
[6] X. Liu, A. Laria, O. Curea, H. Caneblog, "Microgrids and its Coordination Control", IEEE Transactions on Smart Grid, Vol. 2, June 2011.
[7] N.R. Rahmanov, A.M. Hashimov, O.Z. Kerimov, "Effect of Combined Wind and Diesel Generation on Power System Operation", Renewable Energy World Conference, Milan, Italy, 2011.
[8] N.R. Rahmanov, S.T. Ahmadova, J. Bilbao, "Distributed Generation System with Renewable Energy Sources: GRID Modeling and Simulation", IEEE Conference EUROCON 2013, Zagreb, Croatia, pp. 984-992, June 2013.
[9] Y. Ito, Z. Yang, H. Akagi, "DC Microcrid Based Distribution Power Generation System", IEEE International Power Electron Motion Control Conference, Vol. 3, pp. 1740-1745, August 2004.
[10] J. Guerrero, "New Challenges in Coordinated Control and Communications for Microgrids", IEEE Conference EUROCON 2013, Zagreb, Croatia, July 2013.
[11] K. Chao, C. Li, S. Ho, "Modeling and Fault Simulation of Photovoltaic Generation Systems Using Circuit Based Model", International Conference Sustainable Energy Technology, pp. 290-294, November 2008.
[12] D. Zhi, L. Xu, "Direct Power Control of DFIG with Constant Switching Frequency and Improved Transient Performance", IEEE Trans. Energy Conference, Vol. 22, No. 1, pp. 110-118, March 2007.
[13] L. Bo, M. Shahidehpour, "Short Term Scheduling of Battery in a Grid Connected PV/Battery System", IEEE Trans. on Power System, Vol. 20, pp. 1053-1061, May 2005.
[14] "ETAP 6.0 Software, Operation Technology".

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 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). He is the member of IEEE, Academician of International Eco-Energy Academy (Baku, Azerbaijan), Co-Chairman of International Conference on "Technical and Physical Problems of Electrical Engineering" (ICTPE), member of Editorial Boards of International Journal on "Technical and Physical Problems of Engineering" (IJTPE) and Journal of Power Engineering Problems. His publications are more than 200 articles and patents, and also 3 monographs. His research areas are power systems operation and control, distributed systems, hybrid microgrids, renewable energy sources and their integration in power systems, application of artificial intelligence to power systems control design.

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.

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