



University of Kurdistan

Dept. of Electrical and Computer Engineering

Smart/Micro Grid Research Center

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An Intelligent Droop Control for Simultaneous Voltage and Frequency Regulation in Islanded Microgrids

Bevrani H, and Shokoohi S

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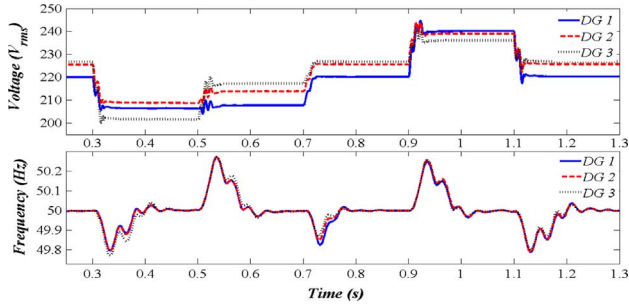


Fig. 11. Voltage and frequency profile under violent load changes.

TABLE II
LOAD CHANGE SCENARIO

Time duration [s]	Load 1 [kVA]	Load 2 [kVA]
0-0.3	30	10
0.3-0.5	30	j40
0.5-0.7	30 +j10	10
0.7-0.9	30	j10
0.9-1.1	0	10
1.1-1.3	30	10

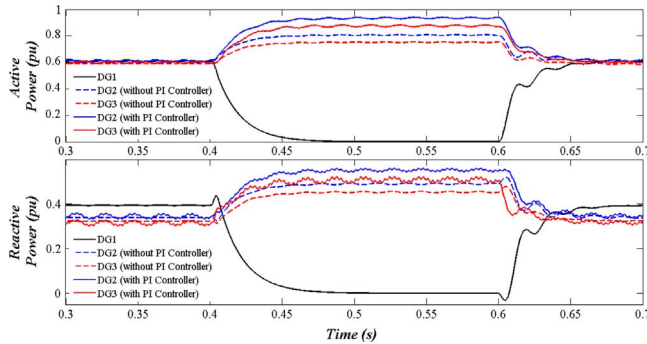


Fig. 12. Output active and reactive power affected by outage of DG 1.

the voltage/frequency deviation. When DG1 is removed, due to lack of secondary control loop, a steady droop is observed in the load voltage terminals. The steady voltage droop can be returned to the nominal operating value by adding a proportional-integral (PI) controller to the voltage control loop (see Figs. 12 and 13). This controller is not activated for the previous test scenario (Fig. 11).

B. 11-Bus Test MG

To prove the reliability of the closed-loop system with the designed ANFIS controller, it is also tested on an 11-bus test system, which is shown in Fig. 14 [30]. At times 0.3 s, 0.5 s and 0.7 s; a load change is occurred in buses 2, 5 and 8, respectively. The loads of the test system before 0.3 s are presented in Table III. This load change scenario is shown in Table IV. The voltage and frequency profile under this load change scenario are shown in Fig. 15.

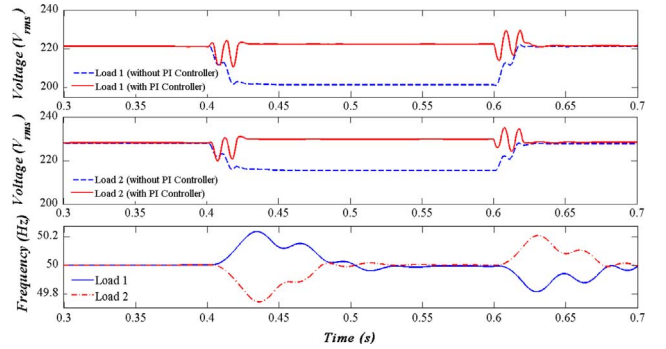


Fig. 13. Voltage/frequency profile of local loads following outage of DG 1.

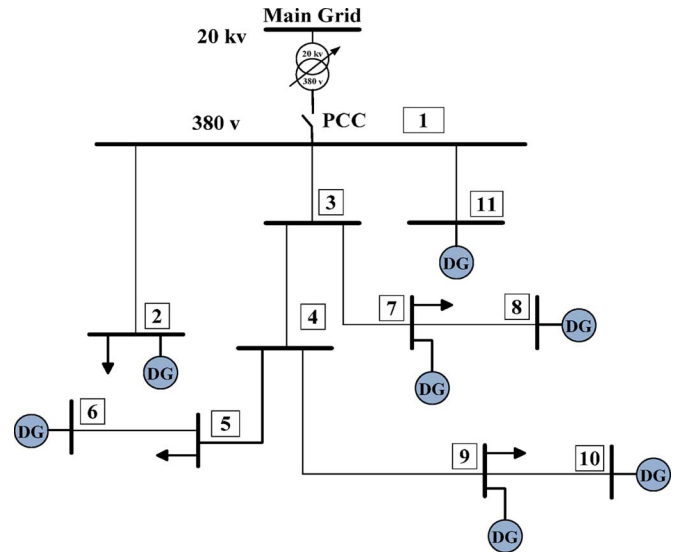


Fig. 14. 11-bus MG test system.

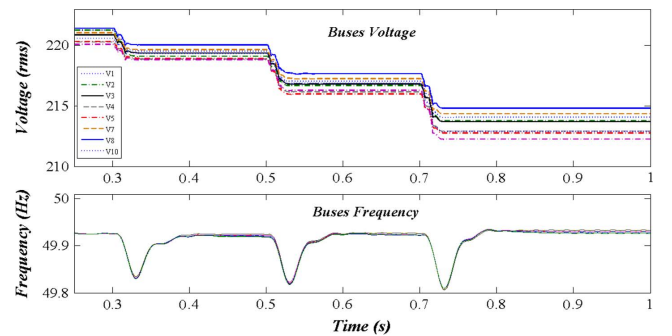


Fig. 15. Frequency and voltage response of 11 bus MG test system in the presence of load change scenario given in Table V.

TABLE III
LOADS IN 11-BUS MG TEST SYSTEM

Bus Number	Load (kVA)
2	20+j10
5	30
7	45
9	25+j10

TABLE IV
LOAD CHANGE SCENARIO FOR 11-BUS MG TEST SYSTEM

	Bus Number	Load Change (kVA)
at $t=0.3s$	2	$10+j3$
at $t=0.5s$	5	$13+j5$
at $t=0.7s$	9	$16+j8$

TABLE V
LOADS IN 14-BUS MG TEST SYSTEM

Bus Number	Load (kVA)
8	$4.25+j2.63$
9	$15.58+j9.66$
10	$13.32+j8.25$
12	$20.45+j12.64$
13	$4.25+j2.63$

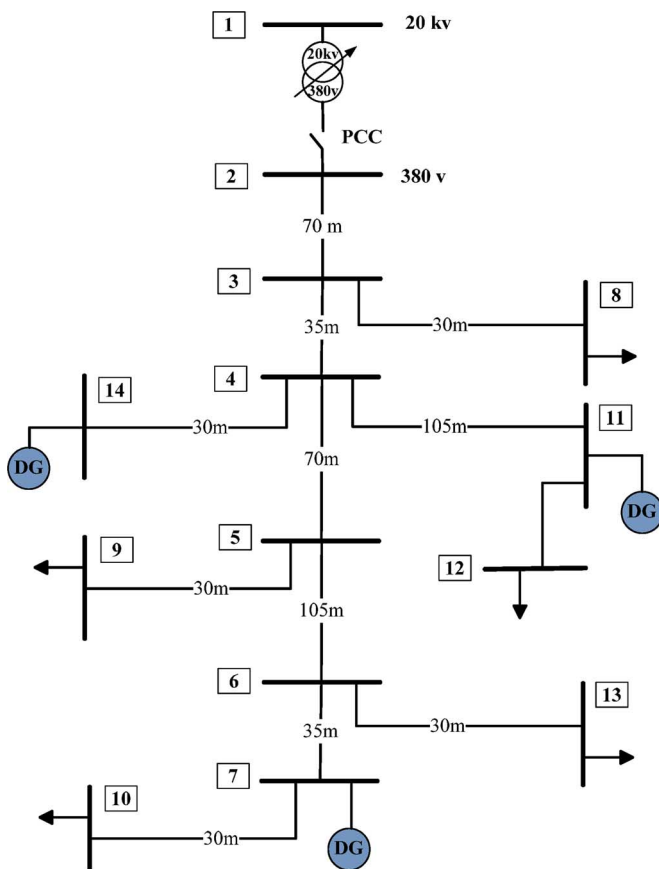


Fig. 16. 14-bus MG test system.

C. 14-Bus Test MG

To investigate the effectiveness of the proposed ANFIS droop controller; it is also examined on a 14-bus test system, which is shown in Fig. 16. This MG is a modified version of the given grid in [31]. At times 0.4 s, 0.6 s and 0.8 s; a load change is occurred in buses 8, 9, and 13, respectively. The loads of the test system before 0.4 s are presented in Table V. The load change scenario is shown in Table VI. The voltage and frequency profile under this load change scenario are shown in Fig. 17. The simulation results show that by the designed ANFIS-based GDC,

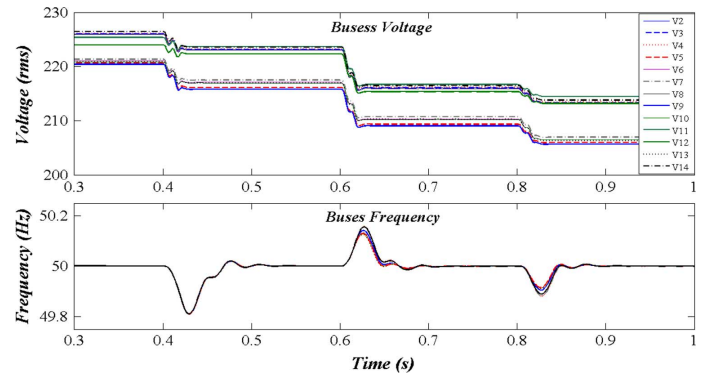


Fig. 17. Frequency and voltage response of 14-bus MG test system in the presence of load change scenario given in Table VII.

TABLE VI
LOAD CHANGE SCENARIO FOR 14-BUS MG TEST SYSTEM

	Bus Number	Load Change (kVA)
at $t=0.4s$	8	$j7$
at $t=0.6s$	9	7
at $t=0.8s$	13	$3+j2$

system stability with desirable performance is guaranteed under severe load changes.

VI. CONCLUSION

The present paper provides a solution for intelligent model-free based generalized droop control (GDC) synthesis for simultaneous voltage and frequency regulation in the islanded microgrids. A GDC is proposed based on the well-known conventional voltage/frequency droops. But the addressed GDC highly depends on the MG configuration and line parameters. To remove this dependency and propose a model-free based GDC, an adaptive neuro-fuzzy inference system (ANFIS) is developed. The ANFIS is responsible to simulate dynamic behavior of the GDC.

The proposed ANFIS is trained by a desired I/O data set of the GDC, and then it is applied to the inverter interfaced DG control structure. Using the developed intelligent GDC synthesis, one does not need more to know the MG structure and line parameters. Thus, this approach is applicable for a wide range of MGs. The effectiveness of the proposed method is examined on several test case systems.

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Hassan Bevrani (S'90-M'04-SM'08) received Ph.D. degree in electrical engineering from Osaka University, Osaka, Japan, in 2004. From 2004 to 2011, he has worked as a post-doctoral fellow, senior research fellow, visiting professor, and professor with Kumamoto University (Japan), Queensland University of Technology (Australia), Kyushu Institute of Technology (Japan) and Osaka University. Since 2000, he has been an Academic Member with the University of Kurdistan, Sanandaj, Iran. He is the author of 3 books, 10 book chapters, and about 150 journal/conference papers. His current research interests include smart grid operation and control, intelligent and robust control applications in power system and power electronic industry.



Shoreshe Shokoohi (S'2011-M'2013) was born in Sanandaj, Kurdistan, Iran, on April, 1987. He received the B.Sc. (with honors) and the M.Sc. degrees in electrical engineering from the University of Kurdistan, in 2009 and 2012, respectively. In 2010, he was with the control laboratory of university of Kurdistan, as a lecturer. He then joined the Instrumentation and Control Unit (ICU) at the Iranian Oil Pipelines and Telecommunication Company (IOPTC). His current research interests are in areas of micro/smart Grids control and robust/intelligent control applications in power electronic industry.