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Resilient Micro Energy Grids for Continuous Production in Oil and Gas Facilities

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Abstract

Oil and gas facilities are required to have continuous production. With recent power supply challenges, it is important to provide reliable and resilient micro energy grid to avoid power interruption and achieve safe operation and shutdown of oil and gas facilities. The proposed power protection strategy is based on the development of micro energy grid with renewable energy sources. Self-healing strategies will be identified against all possible hazards and fault scenarios in oil and gas facility and critical components. This includes safety and performance degradation scenarios, and related power supply issues due to internal and external factors. Risk-based operation scenarios will be evaluated with different micro energy grid designs and configurations. The proposed solution will provide self-healing and recovery operation using advanced and intelligent control devices.

Keywords: Micro energy grid; Self-healing; Risk-management; Power supply; Oil and gas integrated protection

Introduction

With the increase in world population and reduction in natural resources, energy supply is facing challenges to provide adequate energy with acceptable cost while maintaining carbon emission levels. There are major challenges in existing grid such as dealing with new energy generation sources, load/demand balancing, risk/reliability, time delay management, and operation cost. With the introduction of the new technologies involving intellectual networks, it is expected to overcome most of these challenges and provide better performance [1]. In particular, the provision of distributed generation and storage in different hierarchical levels within the grid with dynamic and distributed control and fault detection to provide optimum, steady and safe operation of the grid [2].

Today oil and gas is produced everywhere around the world. It can be either onshore or offshore. The main process consists of wellheads, manifolds/gathering, separation, gas compression, gas compression, metering, storage and export. Vent/Flare, Heat Exchanges, Cooling Tower and Boilers and Furnaces are some of the equipment that is used in the oil and gas plants [3]. In order to find the best power configuration, the power system functional requirements should be collected. In addition, the power system alternatives should be modeled based on the selected criteria. Furthermore, the reliability of the proposed alternatives should be calculated and analyzed. In the end, based on the collected data, the best optimal power system should be selected [4]. The electrical system in a petroleum refinery should be designed for reliable services, minimum power losses, improvement of efficiency, reliability in operational and increase in production [5].

Micro Energy Grid (MEG) is an emerging concept in intellectual networks that integrates different energy resources like electricity, heat, hydrogen, and natural gas. MEG needs to be more reliable, secure, economic, eco-friendly, and safer. The main characteristics of MEG include [6-9] – i) Self-healing: Online self-assessment of the grid operation state, able to detect fault quickly without or with little manual intervention, ii) Interaction: able to incorporate consumer equipment and behavior in the design and operation of the grid, iii) Optimization: able to optimize its capital assets while minimizing operation and maintenance costs in the whole life Cycle, iv) Compatibility: able to accommodate a wide variety of distributed generation and storage options, and v) Integration: intelligent decision support system based on the integration of information. It can be seen from above that safety and sharing are regarded as the core advantage and key technical problem to be tackled of MEGs. However, precise and real-time fault diagnosis has become one of the key requirements in the application of MEG due to its impact on the overall grid safety [10]. This paper examined the power supply of a petroleum refinery. The intention of this research is to create solutions in different ways for a reliable service and minimum power losses in a petroleum refinery.

Micro Grid Design for Oil and Gas Plant

This micro energy grid is designed for Oil and Gas plants. The loads that are used in this project are Boilers and Furnaces, Cooling Tower, Heat Exchanges and Vent/Flare. The proposed hybrid MG consists of PV, wind turbine (WT), Fuel Cell (FC), Battery, Micro Gas Turbine (MGT), AC loads, AC distribution lines, DC distribution lines, DC loads and DC-AC-DC converters. The energy that is produced by DGs is stored in the battery. Figure 1 shows the design of the micro energy grid.

In order to satisfy the energy supply requirements for oil and gas plants, it is possible to utilize higher generation capacity, such as small nuclear power plants. A small nuclear power plant also referred as Small module reactor (SMR) is a new emerging technology which could be compatible as distributed generators. According to the International

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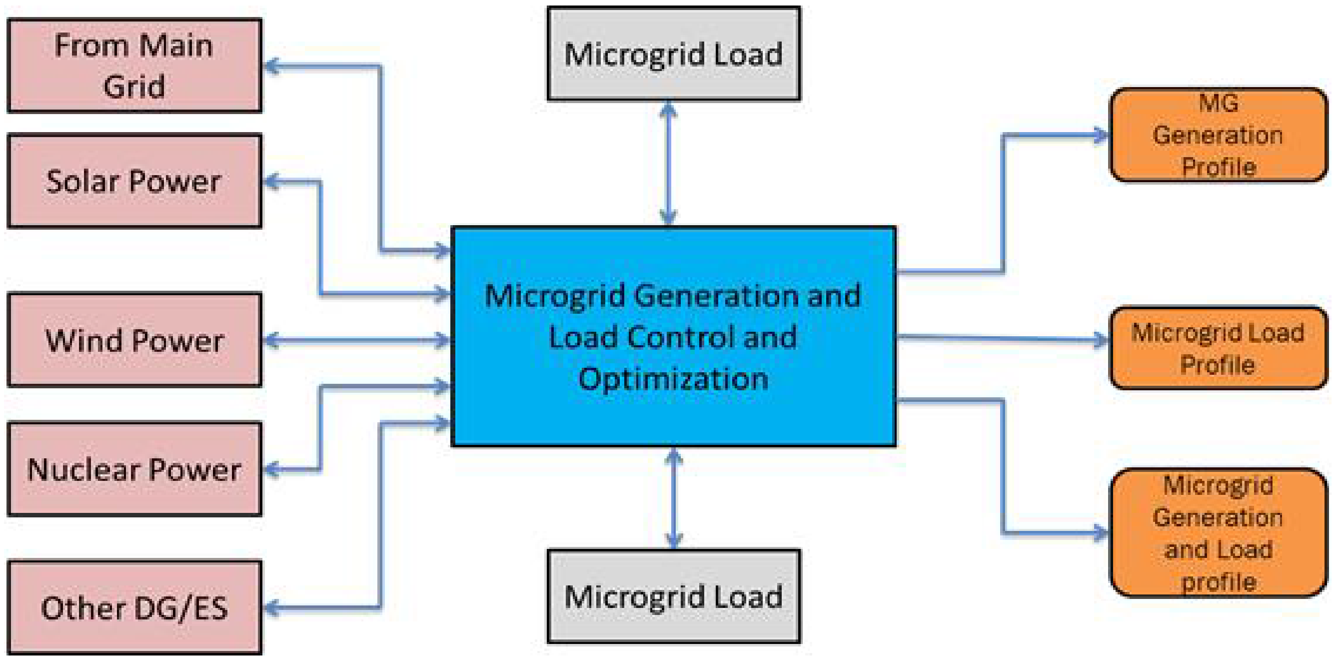

Figure 1: Micro energy grid Generation and Load Infrastructure

Atomic Energy Agency (IAEA), a plant having an electrical output power less than 300 MWe is defined as small modular reactor (SMR) or small nuclear plant [11]. There are varieties of size and technology of the small modular reactor (SMR) which might be an alternative solution for independent micro energy grid. Light water reactor (LWR), fast neutron reactor (FNR) and graphite moderator reactor (GMR) are the main category of small modular reactors and the size could vary from 10 MWe to 300 MWe. Depending on electricity demand one or multiple SMR unit could be installed in same site in a micro energy grid. As SMR could provide continuous power, the access power would be transferred to the main grid. SMR wouldn't be recommended as distributed like solar or wind power because of safety concern. Besides, SMRs would have more installed capacity than gas power plant.

Micro energy grid control optimization can be achieved with distributed control architecture and optimization algorithm that can consider loads and generation sources Figure 1 shows micro energy grid generation optimization to support the existing electrical load and planned distributed generation.

Micro Energy Grid (MEG), as shown in Figure 2, is an emerging concept in intellectual networks that integrates different energy resources like electricity, heat, hydrogen, and natural gas. MEG needs to be more reliable, secure, economic, eco-friendly, and safer.

Operation Strategy for Resilient Energy Supply for Oil and Gas Plant

Two different scenarios were chosen for a micro energy grid with AC loads such as Cooling Towers, Boilers and Furnaces, Heat Exchanges and Vent/Flare. The first one is when the micro energy grid consists of fuel cell, PV, Wind Turbine and battery. The second scenario is when the micro energy grid consists of fuel cell, PV, Wind Turbine, battery and micro gas turbine.

Results and Discussions

Bus 1 is connected to the grid and Bus 2 is connected to AC distributed energy sources. Bus 3 is connected to DC distributed energy sources. Figures 3-5 show the three phase voltages in different buses in scenario one when the micro energy grid is connected to the grid. Figures 6-8 show the active and reactive power in scenario one when the micro energy grid is connected to the grid. Figures 9 and 10 show the three phase voltages in different buses when the micro energy grid is in islanding mode in scenario one. Figures 11 and 12 show the active and reactive power in scenario one when the micro energy grid is in islanding mode. Figures 13-15 show the three phase voltages in different buses in scenario two when the micro energy grid is connected to the grid. Figures 16-18 show the active and reactive power in scenario two when the micro energy grid is connected to the grid. Figures 19 and 20 show the three phase voltages in different buses when the micro energy grid is in islanding mode in scenario two. Figures 21 and 22 show the active and reactive power in scenario two when the micro energy grid is in islanding mode. Table 1 shows THD at different buses. In addition Table 2 shows the power factor at different buses. Table 3 shows the modulation index in different scenarios.

Conclusion

Oil and gas facilities are required to have a reliable power system in order to have a continuous production. This paper examined a proposed power control strategy is based on the development of micro energy grid with renewable energy sources. The proposed hybrid MG consists of PV, wind turbine (WT), Fuel Cell (FC), Battery, Micro Gas Turbine (MGT), AC loads, AC distribution lines, DC distribution lines, DC loads, DC-AC-DC converters and battery. The first scenario that was examined in this paper is when the micro energy grid consists of fuel cell, PV, Wind Turbine and battery. The second scenario is when the micro energy grid consists of fuel cell, PV, Wind Turbine, battery and micro gas turbine. Both of these scenarios were examined in grid-connected and islanding mode. Risk-based operation scenarios are

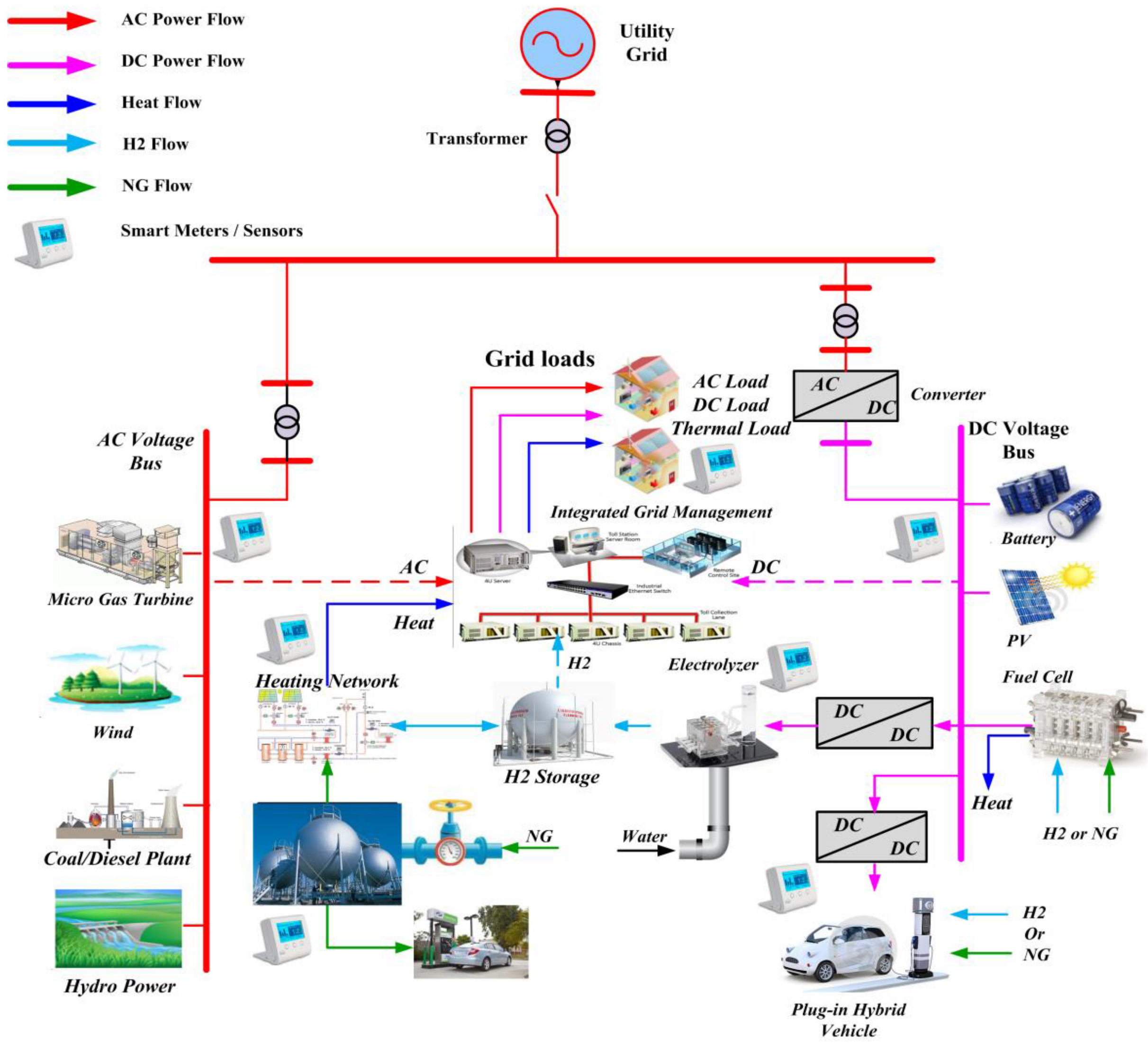

Figure 2: Micro Grid Design for Oil & Gas Plant

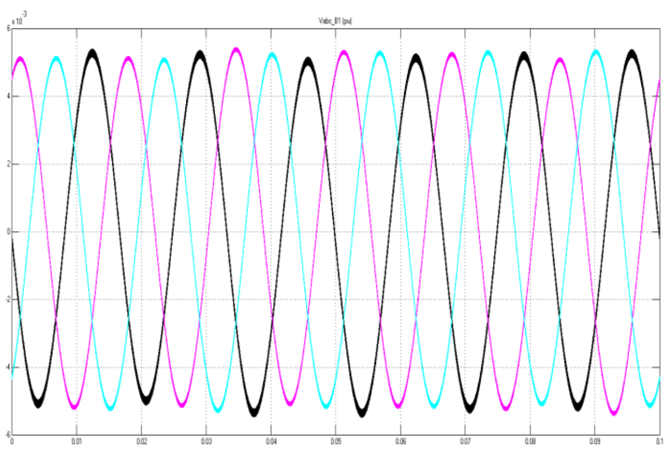

Figure 3: V_{abc} at bus 1 in Grid-connected scenario 1

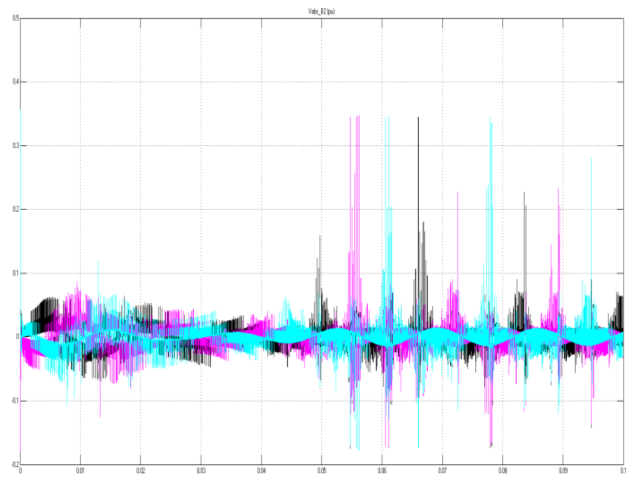

Figure 4: V $_{abc}$ at bus 2 in Grid-connected scenario 1v

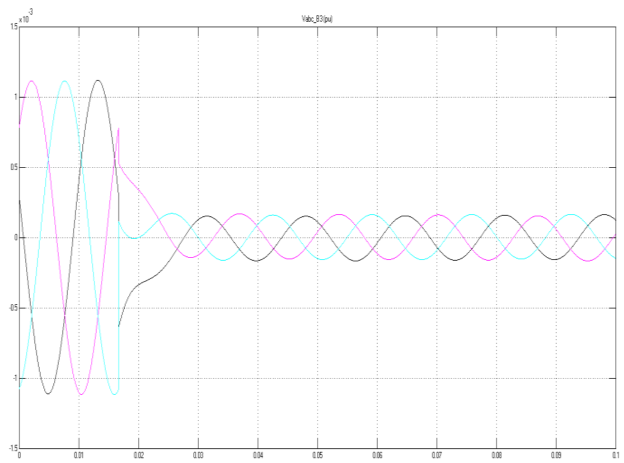

Figure 5: V $_{abc}$ at bus 3 in Grid-connected scenario 1

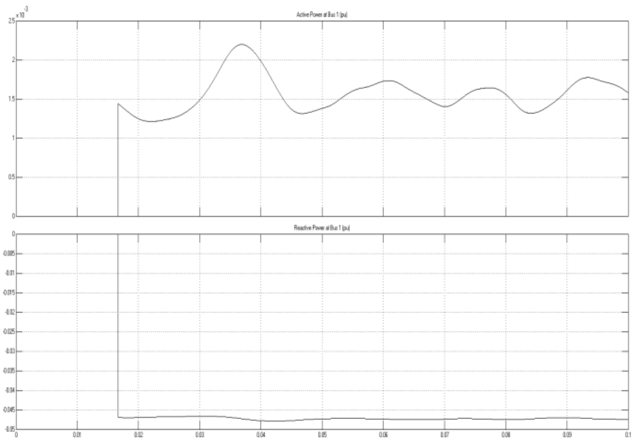

Figure 6: Active and Reactive Power at bus 1 in Grid-connected scenario 1

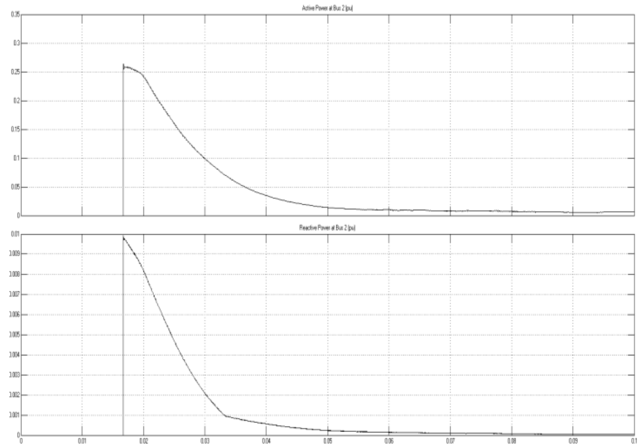

Figure 7: Active and Reactive Power at bus 2 in Grid-connected scenario 1

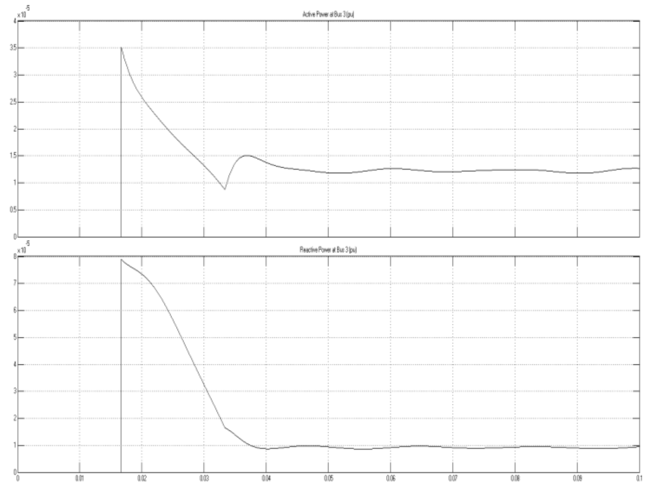

Figure 8: Active and Reactive Power at bus 3 in Grid-connected scenario 1

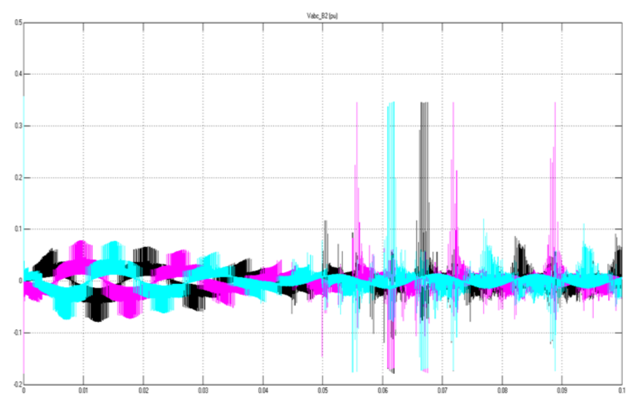

Figure 9: V $_{abc}$ at bus 2 in Islanding scenario 1

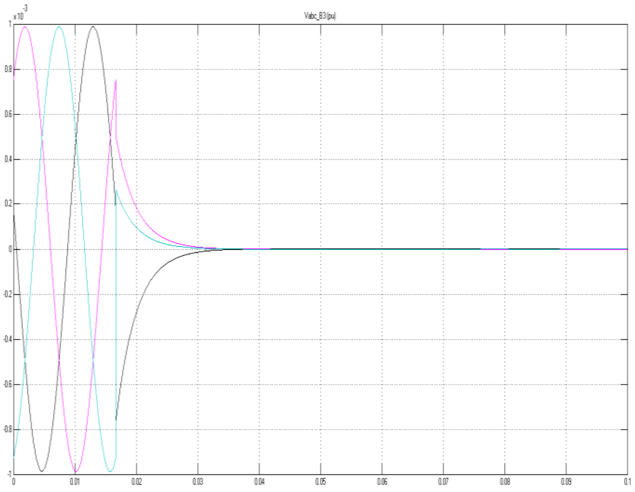

Figure 10: V $_{abc}$ at bus 3 in Islanding scenario 1

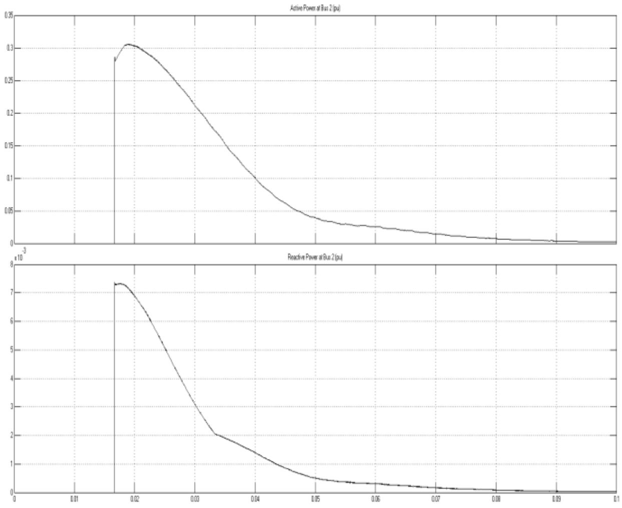

Figure 11: Active and Reactive Power at bus 2 in Islanding scenario 1

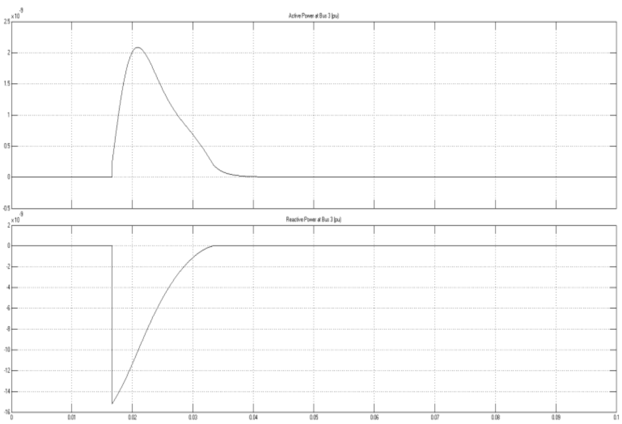

Figure 12: Active and Reactive Power at bus 3 in Islanding scenario 1

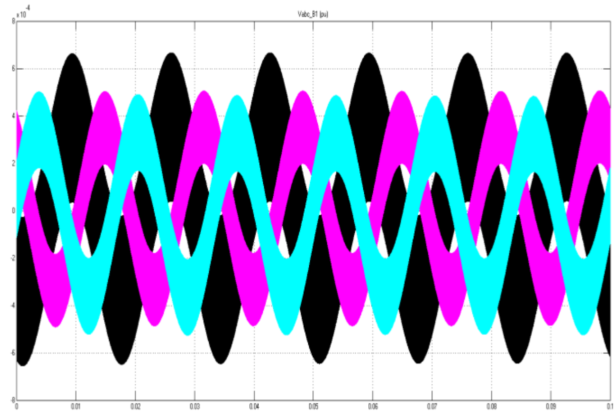

Figure 13: V $_{abc}$ at bus 1 in Grid-connected scenario 2

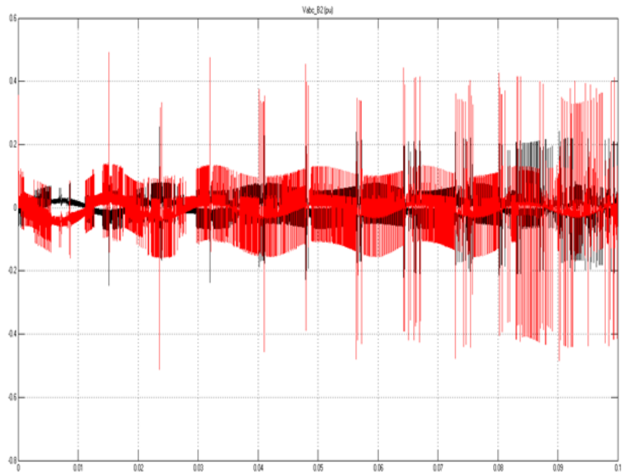

Figure 14: V $_{abc}$ at bus 2 in Grid-connected scenario 2

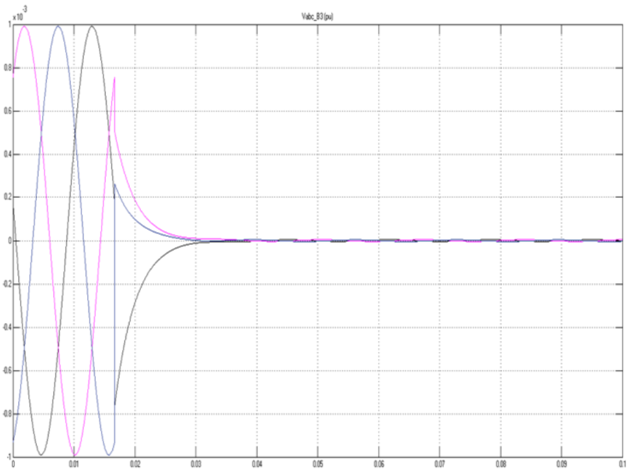

Figure 15: V $_{abc}$ at bus 3 in Grid-connected scenario 2

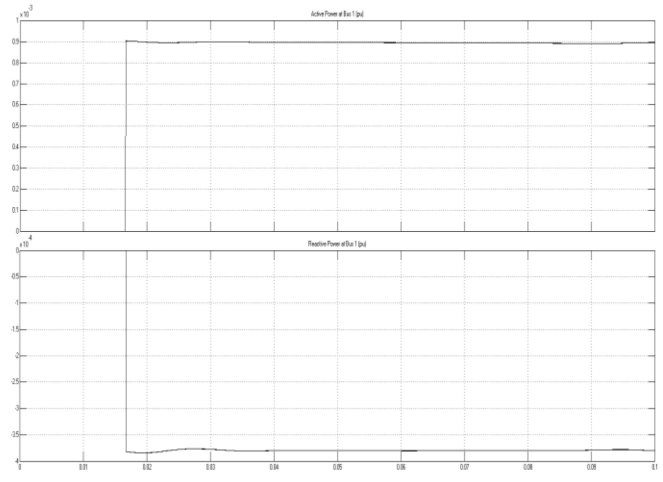

Figure 16: Active and Reactive Power at bus 1 in Grid-connected scenario 2

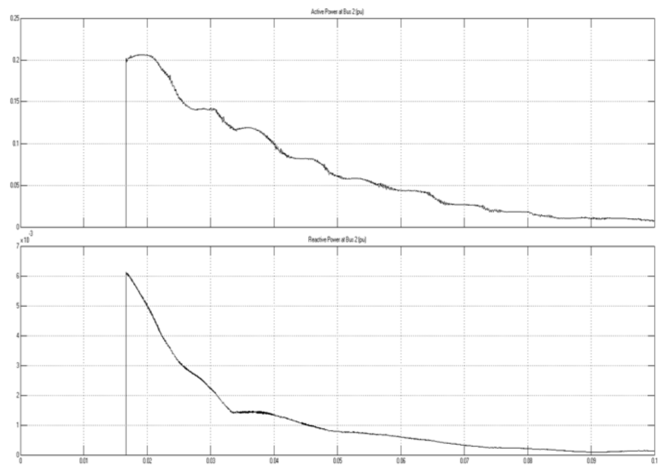

Figure 17: Active and Reactive Power at bus 2 in Grid-connected scenario 2

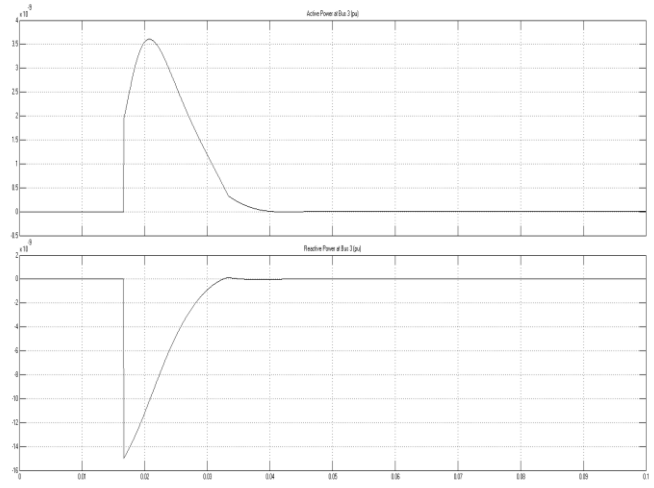

Figure 18: Active and Reactive Power at bus 3 in Grid-connected scenario 2

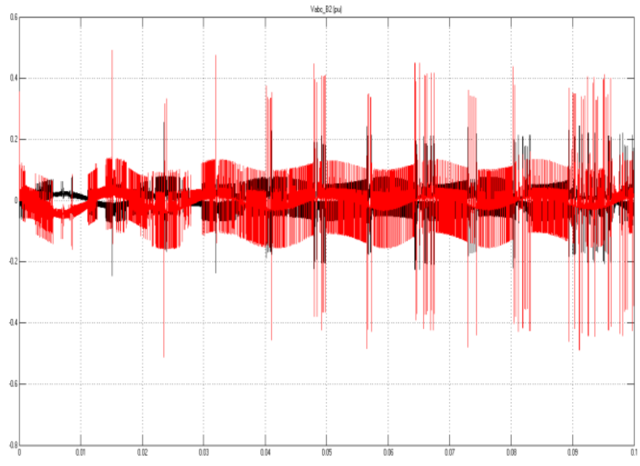

Figure 19: V_{abc} at bus 2 in Islanding scenario 2

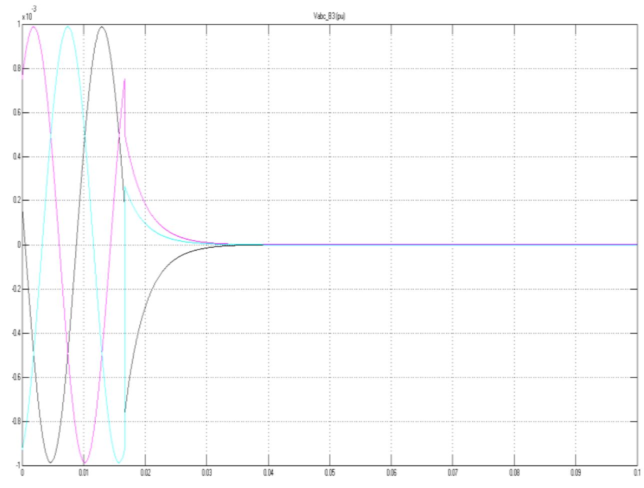

Figure 20: V_{abc} at bus 3 in Islanding scenario 2

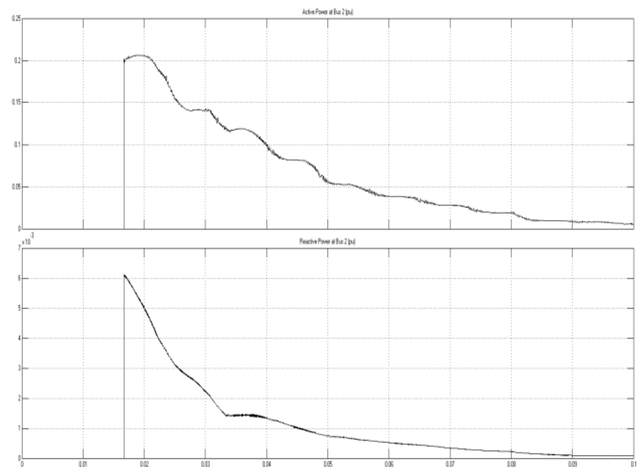

Figure 21: Active and Reactive Power at bus 2 in Islanding scenario 2

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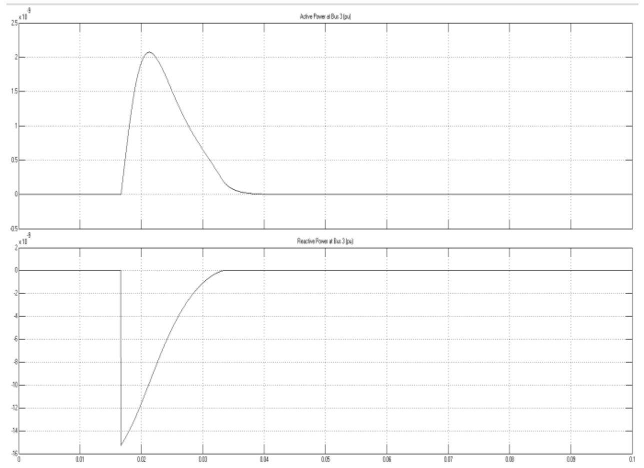

Figure 22: Active and Reactive Power at bus 3 in Islanding scenario 2

THD %	Scenario1 Grid-connected	Scenario1 Islanding	Scenario 2 Grid-connected	Scenario 2 Islanding
Bus 1	0.6926	-----	0.1988	----
Bus 2	5.599	4.7	13.5	12.11
Bus 3	0.6839	0	0.2485	0

Table 1: THD at different buses

Power Factor	Scenario1 Grid-connected	Scenario1 Islanding	Scenario 2 Grid-connected	Scenario 2 Islanding
Bus 1	0.9913	-----	0.9913	------
Bus 2	1	1	1	1
Bus 3	0.9992	0.9938	0.9228	0.9933

Table 2: PF at different buses

Scenario	Modulation Index
Scenario1 Grid-connected	0.2984
Scenario1 Islanding	0.1491
Scenario 2 Grid-connected	0.1525
Scenario 2 Islanding	0.09259

Table 3: Modulation Index in different scenarios

evaluated with different micro energy grid designs and configurations. The proposed solution provides self-healing and recovery operation using advanced and intelligent control devices.

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