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Control Strategies for Supply Reliability of Microgrid

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***Abstract*-- Maintaining security, reliability and acceptable power quality are important in power system. Microgrid can be used to ensure them in its concerned region. Microturbine which can be used for Combined Heat and Power (CHP) application is considered as microsource in this paper. Microsources are generally dispersed so use of decentralized control system is convenient. A simple model is proposed for microsource control in microgrid based on droop control in islanded mode and PQ control in grid connected mode. A simulation model of microgrid is developed by using MATLAB-simulink platform. Performance of microgrid is studied under grid connected and islanded mode.**

Keywords–Reliability, distributed generation, microgrid, CHP application, droop control..

I. INTRODUCTION

The power system consists several loads which require quality power for their proper functioning. Popular technologies which can provide quality power during the failure of grid include use of Microturbines, Fuel cells and renewable energy sources like wind turbine and solar Photo Voltaic. Due to dispersed nature of microsources use of decentralized control for inverters is convenient. A microgid having 3 feeders out of which two feeders having sensitive load is considered and frequency droop controller is used for active power control in microgrid [1] .A generating system having a dc stage before inverter is considered and is assumed that power demand is within the capability of the device. Analysis is done on inverter control with two control techniques, PQ control in grid connected and droop control in islanded mode. By using these techniques transition between two modes is easy under both single and multi inverter operation [2]. A test system with PV, Single Shaft MT, Single Shaft, fuel cell is considered. System is then tested for Single Master Operation and Multi Master Operation in islanded mode with load following. Both are effective, efficient and can ensure stable operation. Secondary controller is must, to retain frequency to nominal value [3]. The basics of distributed generation and MT are discussed [4]. Modeling of MT is performed using GAST model. Its performance is studied under grid connected and islanded mode[5]. Various battery models are discussed including thevinin model, linear electrical model, non linear electrical circuit. Thevinin model is less accurate, Linear electrical model is more accurate but temperature dependence factor is not considered. A non linear electrical circuit is built considering temperature dependence and is verified experimentally [6].

II. CONTROL OF MICROSOURCE

Most of the microsources produce electrical output of frequency different from that of utility grid. So inverter interface is required. As MS we are considering is MTG it produces output with high frequency. So it to be converted to DC by rectifier and is fed to a battery. The output of battery is converted to AC by inverter and is fed to microgrid.

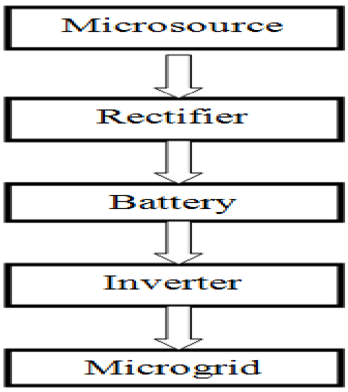

Fig.1. Control of microsource having inverter interface.

III. CONTROL ARCHITECTURE OF MICROGRID

Autonomous control of MG is considered in this paper. There is no central controller which controls entire microgrid, Each MS is controlled autonomously. In this architecture there are 3 types of control configurations.

1. Unit power flow control configuration
2. Feeder power flow control configuration.
3. Mixed power flow control configuration

Unit Power Control Configuration:

According to this configuration the voltage magnitude at the pcc or at output terminal and power injected by the source controlled by MS. Each unit operates as constant power source and if load tends increases anywhere in MG it is met by utility grid. In islanding condition frequency vs. active power droop and voltage magnitude vs. reactive power droop controllers are used for power sharing between microsources in microgrid.

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IV. CONTROL OF INVERTERS

Two types of control systems are adopted.

1. PQ control:

The inverter output voltage is to be synchronized with the grid voltage which is controlled in amplitude and phase. The inverter is provided with active and reactive power set-point so that output current of the inverter is defined. It can be used in grid connected mode to exchange active and reactive power with the grid. In this case inverter can be viewed as a current controlled voltage source.

2. Droop Control:

The inverter acts as a voltage source with magnitude and frequency controlled by droop equations.

$$\omega_1 = \omega_0 - M * (P_{0i} - P_i)$$

$$V_1 = V_0 - N * (Q_{0i} - Q_i)$$

The inverter is controlled to supply the load with given values of voltage and frequency. Depending on the load demand at such new voltage and frequency, the inverter real and reactive output will be defined automatically. The voltage droop controller is used for reactive power sharing and frequency droop controller for active power sharing.

Frequency vs. Active power droop:

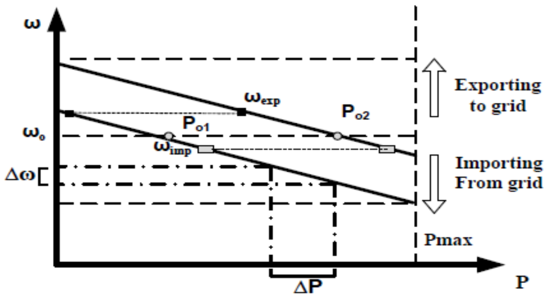

Fig 2 f vs. P droop

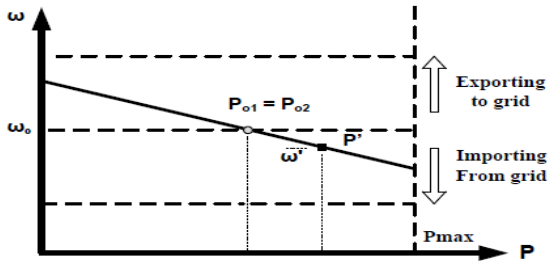

Fig 3 f vs. P droop for identical inverters

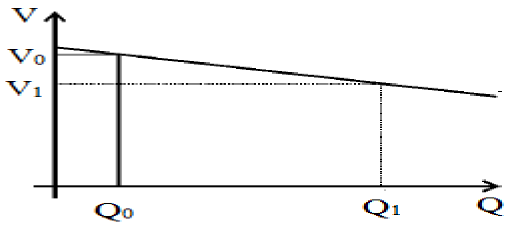

Fig 4 V vs. Q droop for identical inverters

Let ωo is grid frequency of inverter prior to islanded condition. If MG transfers to islanded mode when importing power from utility grid the frequency decreases increasing power output of both the inverters. Similarly, If MG transfers to islanded mode when exporting power from utility grid the frequency decreases increasing power output of both the inverters. If both the inverters are identical and maximum power that can be delivered by both the inverters are same then f vs. P droop of inverters are as shown in figure 3 and V vs Q droop is as shown in fig 4. The load demand is shared by both the inverters equally

V. SIMULATION OF MICROGRID

Fig shows block diagram of proposed MG. It consists of two MS 1 and 2 which are Microturbines and two loads 1 and 2, Static switch(SS), installed at PCC. SS can island the MG in case of faults, power quality events and IEEE 1547 events autonomously. In such cases loads 1 and 2 receive power from MG only.

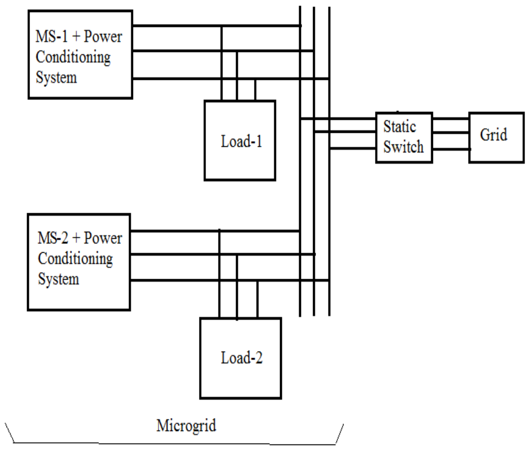

Fig 5. Block diagram of considered MG

Dynamics of turbine and generator are neglected, The entire Turbine-Generator-Rectifier group is modeled as a simple DC current source. Thevinin model is considered for modeling the battery.

Simulation of frequency vs. active power droop:

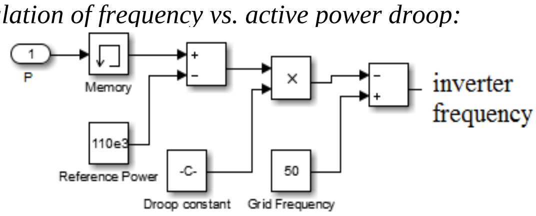

Fig.6 F Vs.P Droop

Simulation of voltage magnitude vs. reactive power droop:

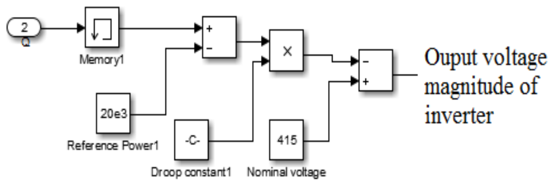

Fig.7 V vs. Q droop

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Simulation of inverter control in grid connected mode:

Only primary controls are considered for generator i.e, balancing supply and load demand. So, DC voltage is kept constant.

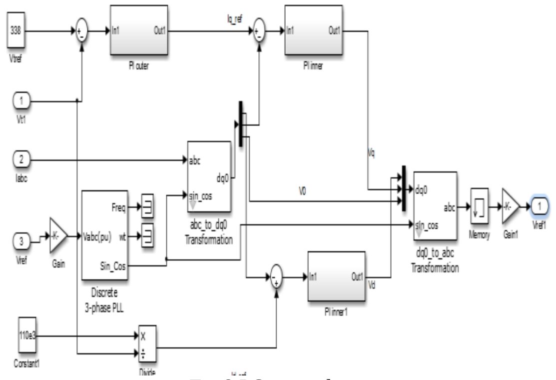

Fig.8 PQ control

VI. RESULTS AND DISCUSSION

Case-1:

Performance of Microgrid connected with equal R-loads on both MS:

Initially the load on each MS is 30KW and MG is operating in parallel with utility grid. During this time the MG has excess power and exports power to utility grid. At 0.1 sec additional load of 130KW is added. During this time the MG has deficient power and imports power from utility grid.At 0.15sec MG is isolated from utility grid. So frequency drops to 49.5Hz so as to increase power output of inverters. At 0.3sec again an additional load of 100KW is added to each MS.Again frequency drops to 48.5Hz to increase power output of inverters

Case-2:

Performance of Microgrid connected with unequal R-loads on both MS

Initially the load on each MS is 30KW and MG is operating in parallel with utility grid. During this time the MG has excess power and exports power to utility grid. At 0.1 sec additional load of 130KW is added. During this time the MG has deficient power and imports power from utility grid. At 0.15sec MG is isolated from utility grid. So frequency drops to 49.4Hz so as to increase power output of inverters.At 0.3sec again an additional load of 100KW is added to MS-1and 50KW to MS-2. Again frequency drops to 48.7Hz to increase power output of inverters and to share the load equally.

Case-3:

Performance of microgrid connected with equal RL-loads on both MS:

Initially the load on each MS is 30KW and MG is operating in parallel with utility grid. During this time the MG has excess power and exports power to utility grid.At 0.1 sec additional load of 20KW at power factor of 0.9 is added. During this time the MG has excess power and exports power to utility grid.At 0.15sec MG is isolated from utility grid. So frequency increases to 50.6Hz so as to decrease active power output and voltage magnitude of inverter output decreases to 414.85V(cal.) so as to increase reactive power output of inverters At 0.3sec again an additional load of 20KW is added to both MS. Again frequency increases to 50.4Hz and voltage magnitude decreases to 414V to decrease active power output and increase reactive power output of inverters.

Case-4:

Performance of microgrid connected with unequal RL-loads on both MS:

Initially the load on each MS is 30KW and MG is operating in parallel with utility grid. During this time the MG has excess power and exports power to utility grid. At 0.1 sec additional load of 10KW at power factor of 0.9 is added to load-1, 20KW at power factor of 0.9 to load-2. During this time the MG has excess power and exports power to utility grid. At 0.15sec MG is isolated from utility grid. So frequency increases to 50.65Hz so as to decrease active power output and voltage magnitude of inverter output decreases to 414.7V so as to increase reactive power output of inverters and share the load equally. At 0.3sec again an additional load of 20KW is added to both MS. Again frequency increases to 50.4Hz and voltage magnitude decreases to 414V to decrease active power output and increase reactive power output of inverters.

Case-5:

Performance of Microgrid reconnected to to utility grid **:**

At 0.5 sec the MG is reconnected to the utility grid, So again the power output of inverter changes to 110KW and MG imports power from utility grid (case-1 loading condition).

Table-1: Inverter currents in islanded mode:

Loading of inverters	MS-1 (A)	MS-2 (A)
160+160KW at UPF	226	226
260+260KW at UPF	366	366
260+210KW at UPF	320	320
50+50KW at 0.9pf	75	75
40+50KW at 0.9pf	70	70
70+70KW at 0.9 pf	106	106

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VII. SIMULATION RESULTS

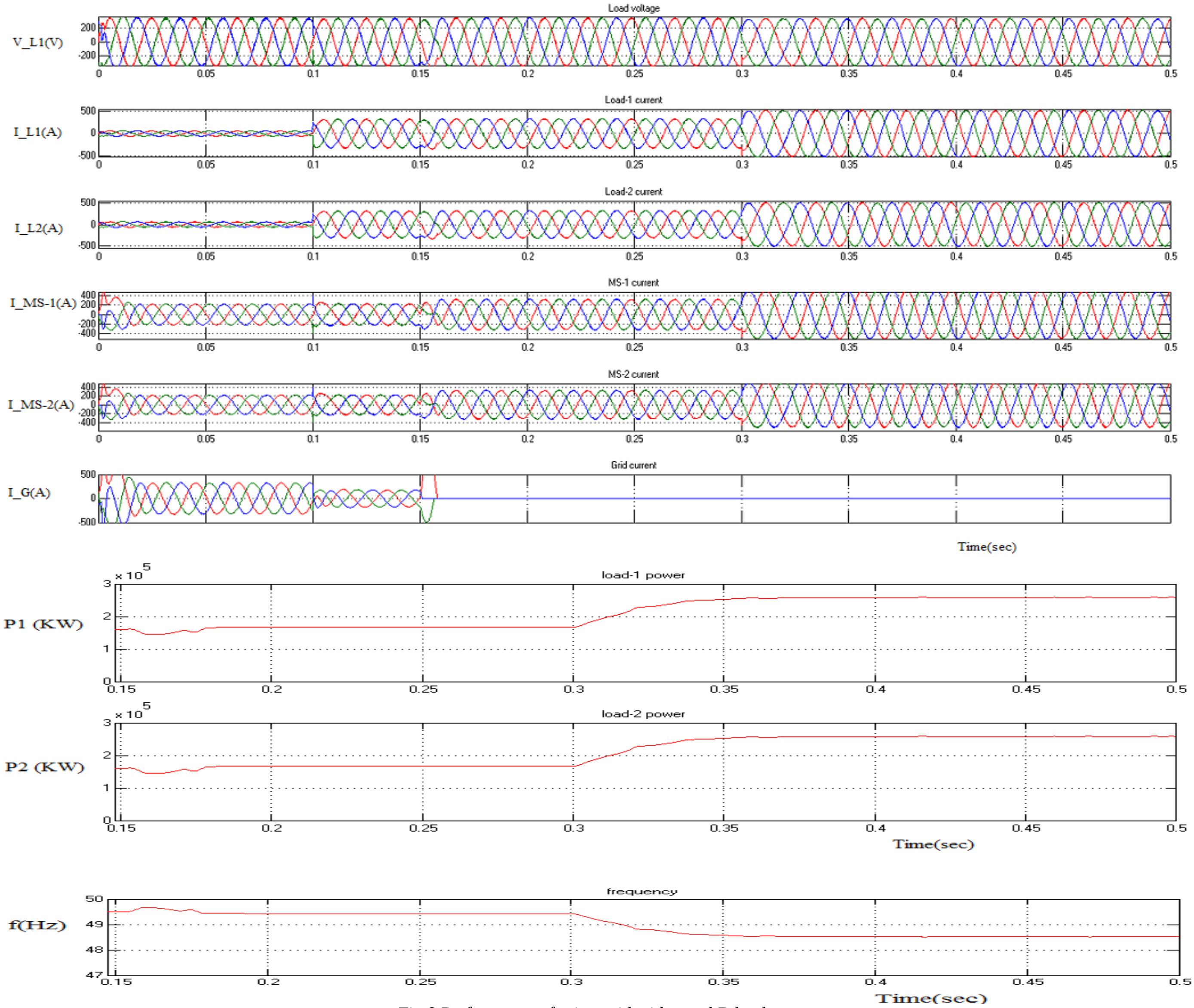

Fig 8 Performance of microgrid with equal R loads:

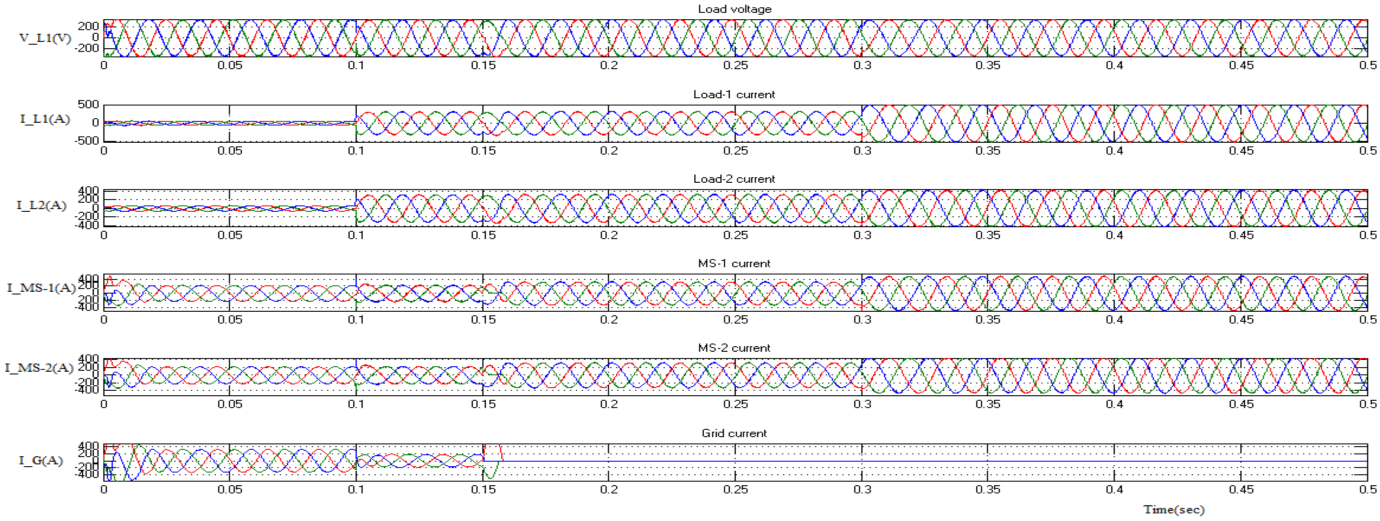

Fig 9 Performance of microgrid with unequal R loads

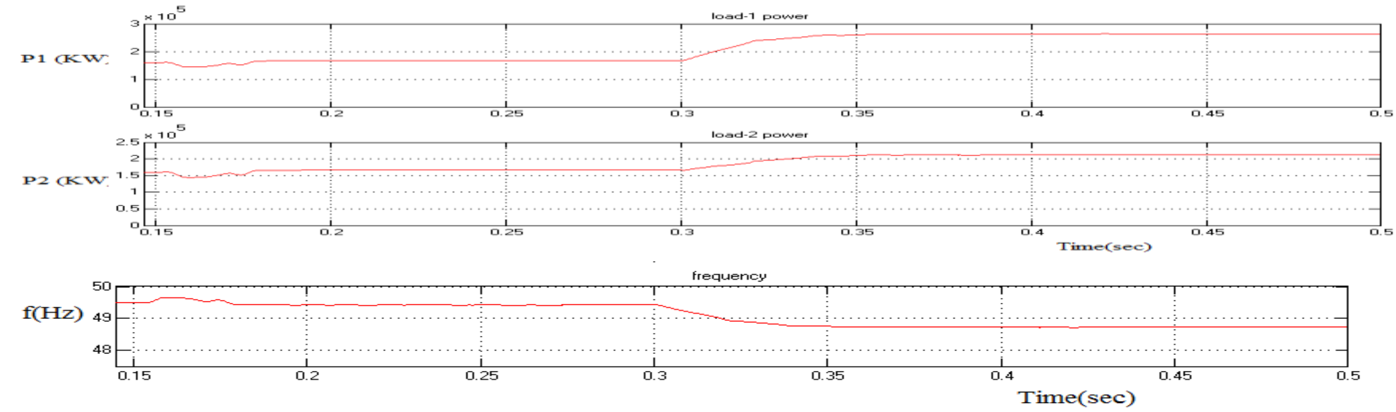

Fig 10 Performance of microgrid with unequal R loads

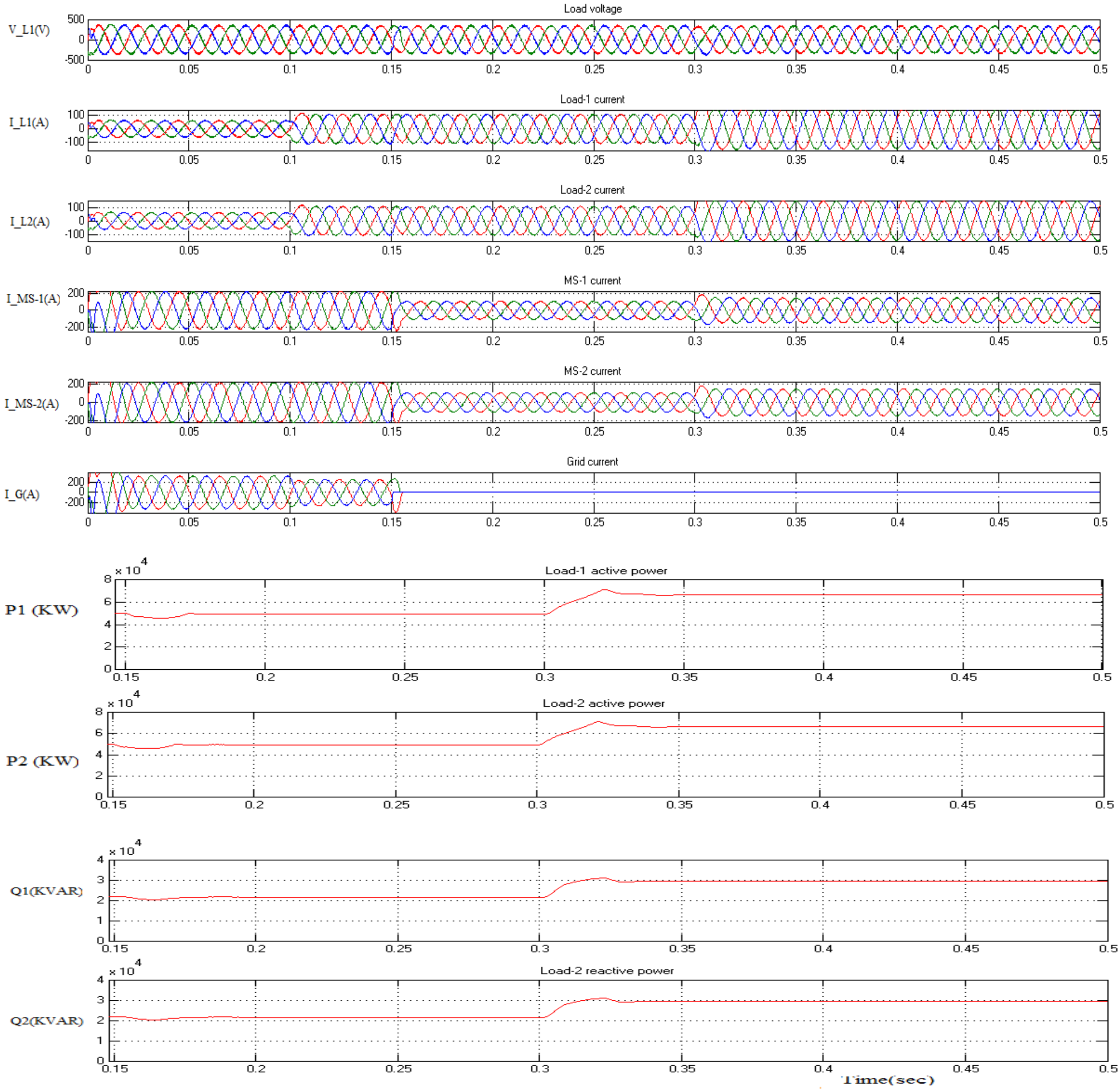

Fig 11 Performance of microgrid with equal RL loads

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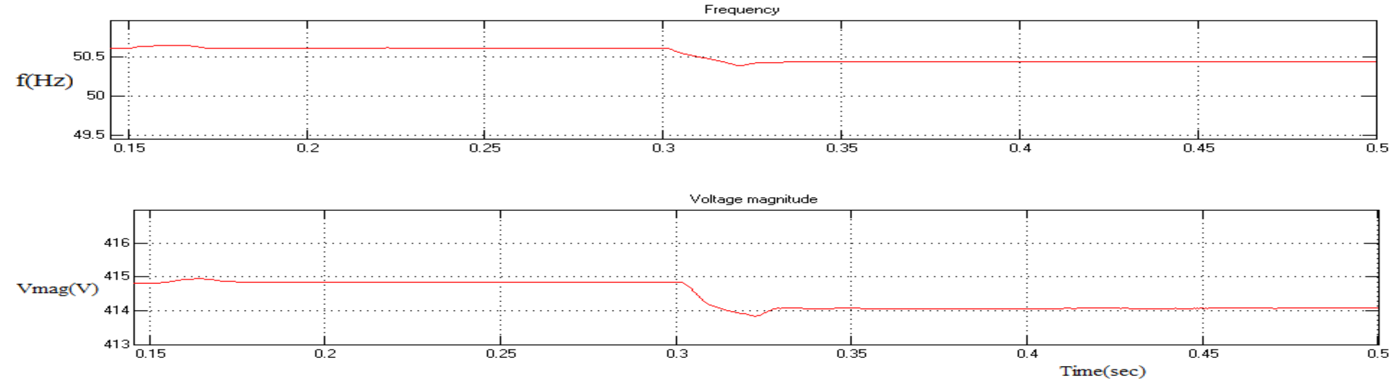

Fig 12 Performance of microgrid with equal RL loads

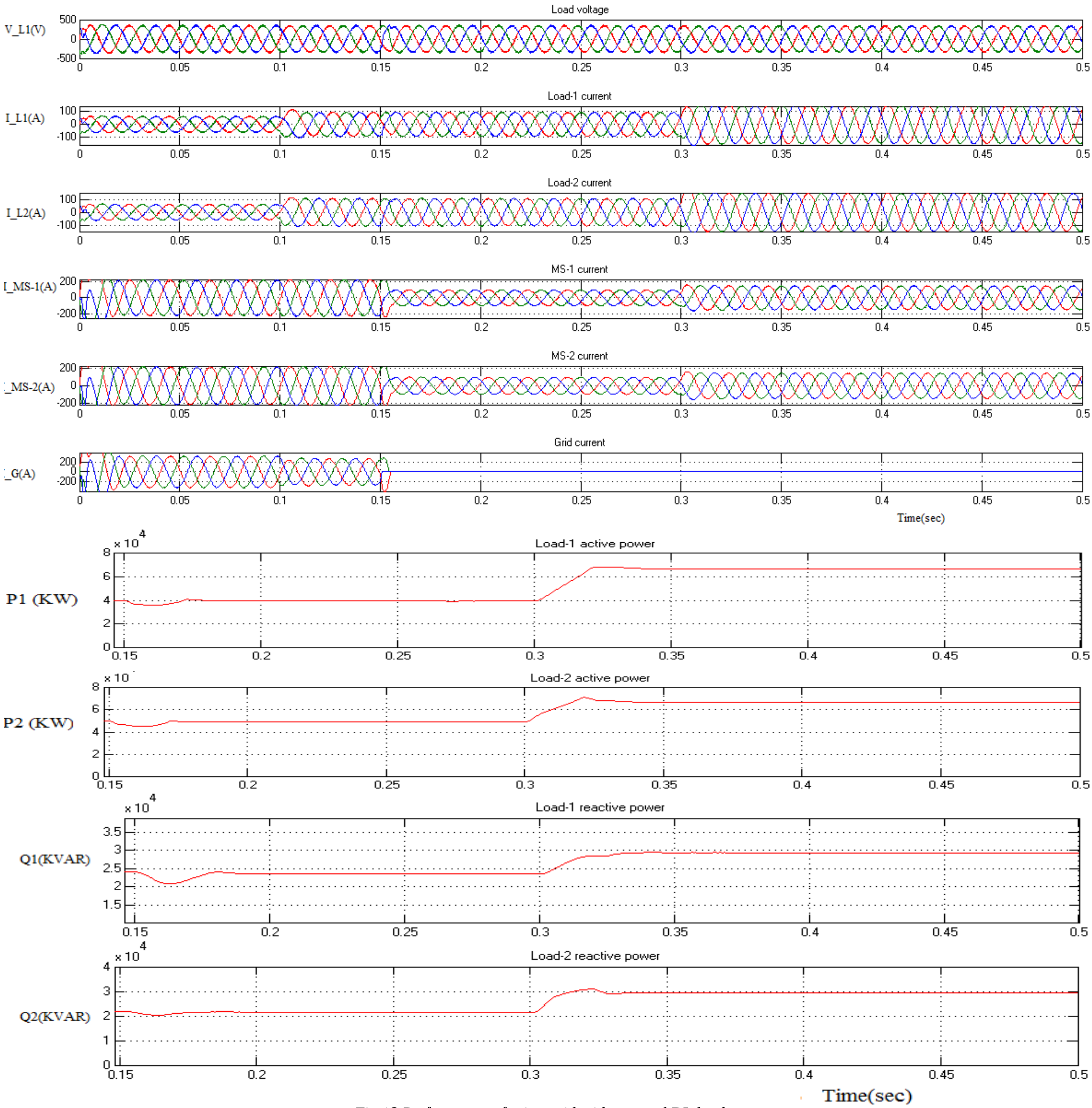

Fig 13 Performance of microgrid with unequal RL loads

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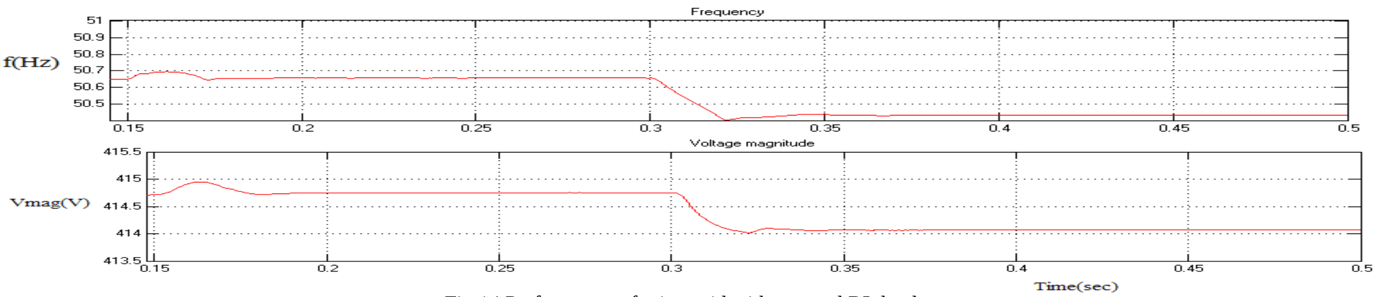

Fig 14 Performance of microgrid with unequal RL loads

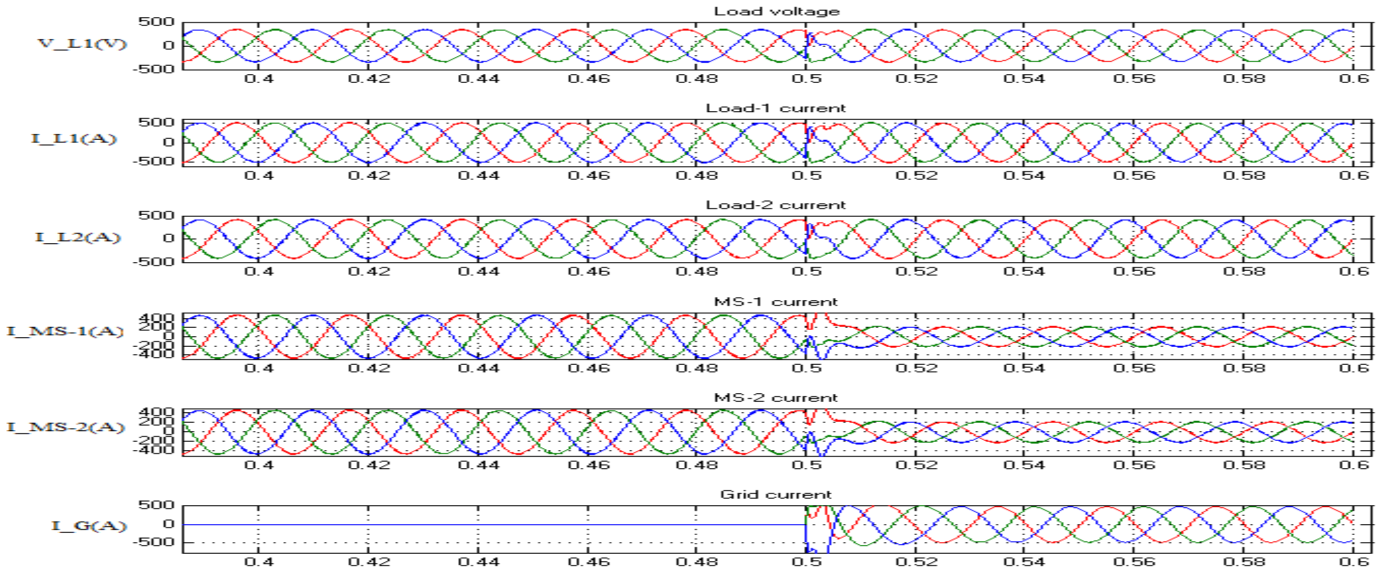

Fig 15 Performance of Microgrid reconnected to to utility grid

In simulink results voltage magnitude and frequency are represented only for islanded mode because in grid connected mode frequency and voltage magnitude are same as that of utility grid.

NOTATION USED:

I_L1 = Current at load-1
I_L2 = Current at load-2
I_MS-1 = Current at microsource-1
I_MS-2 = Current at microsource-2
P1 = Load-1 active power
P2 = load-2 active power
Q1= Load-1 reactive power
Q2= Load-2 reactive power
f = frequency
Vmag = Voltage magnitude

CONCLUSIONS:

By using this control system loads receive continuous power supply. So the proposed control system can be used for critical loads. Each microsource can be controlled autonomously without using complex control system.

APPENDIX:

Inverter and system specification:
VSI using IGBT, 415V ac supply
L_f = 800 µH, R_f = 0.004Ω, C = 1500µF,
Ll = 100 µH
Battery specification:
R_1= 10KΩ, R =0.1Ω, C_1 = 25000F, V_{oc} = 750V
Grid specification:
5MVA, 415V, 50Hz.

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