January - February 2020
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Augmentation of Low Voltage Ride Through in AC Microgrid using Fault Current Limiting Function of Supercapacitor

Pretty Mary Tom
Research Scholar, SELECT, VIT University, Vellore

Dr. Belwin Edward J
Associate Professor
SELECT, VIT University, Vellore.

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Abstract:
Power generation from renewable energy sources is fluctuating in nature, and addition of an energy storage system to the microgrid is indispensable. Here, a fault current limiting scheme is proposed using supercapacitor in fusion energy storage system. The system constitutes PV and WT as sources and battery-supercapacitor as combined energy storage backup. The controller switches the supercapacitor so as to limit the increase in current due to fault, which prevents tripping of generator and thus aiding low voltage ride through. The proficiency of the anticipated modeled system is validated by simulating the major faults in the modelled microgrid. The system is modelled in MATLAB/ Simulink background and studied.

Keywords: *Augmentation, Low Voltage Ride, AC Microgrid.*

I. INTRODUCTION

As the mandatory need for electric power is increasing together with fast depletion of fossil fuels and associated global warming, renewable energy sources (RES) have gained much importance. Photovoltaic (PV) generators and Wind turbine (WT) are utilized all over the world to supply electricity to consumers in inaccessible areas. The intermittent and fluctuating nature of renewable sources is overcome by combination of two or more renewable sources, which is known as hybrid renewable energy systems (HRES) [1].

For a PV/WT hybrid system, it is obligatory to provide an energy storage device. The storage system encounters the remaining requirement when the renewable sources produce low energy. The storage device can be a battery, supercapacitor, Superconducting Magnetic Energy Storage, or an FC/electrolyze system [8]. These renewable sources together with storage devices form a Microgrid. Microgrids (MG) are defined as systems that have at least one distributed energy source and related loads, which can allow deliberate islanding in the electrical distribution systems, i.e. they can work when allied to grid and also in islanded mode [2].The MG technology offers upgraded service consistency, better finances, and a reduced reliance on the local utility.

The power system link is more delicate to grid disturbances due to the increased penetration of renewable sources. According to grid code requirements, low voltage ride through (LVRT) is necessary to preserve system stability. The duration and extent to which the voltage can fall before the generator gets disconnected from the grid is known as LVRT or fault ride through (FRT) [3]. The WT is expected to stay connected to the grid and withstand abnormal condition. Different countries have different grid code requirements.

Various techniques have been suggested by scholars to achieve LVRT in HRES systems. Traditionally devices were installed externally for enhancing the capability of LVRT where a converter in series to the hybrid microgrid is devised for improving the quality of power via eliminating the voltage swell and sag [5]. At the beginning these requirements were only applied to wind turbines, nowadays it is to be satisfied by photo voltaic systems (PV) also [6].

In this paper LVRT of DFIG wind turbines is concentrated. Numerous methods have been discussed in connection with the LVRT capability enhancement of wind turbines, some of which are discussed below. A resistive crowbar network was introduced which limits fault current but loss in magnetisation in rotor side causes absorption of reactive power and further drop in voltage [7]. High cost and complexity of Dynamic Voltage Restorer, together with its ineffectiveness limits its use in LVRT, for detecting and compensating sags [4]. Flexible AC Transmission System (FACTS) devices like STATCOM and UPFC have also been conversed by authors but its efficacy in improving LVRT in case of unbalanced faults is not clear [9]. During asymmetrical fault stabilized control was achieved by incorporating a bridge type fault current limiter [10].

II. SYSTEM UNDER STUDY

The hybrid microgrid configuration under study consists of photovoltaic generator and DFIG wind turbine reinforced by combination energy storage which included battery and supercapacitor. The hybrid energy storage is supposed to provide both transient and steady state changes in generation and loads [11]. The system is modelled in MATLAB/ SIMULINK/ SIMPOWERSYSTEMS.

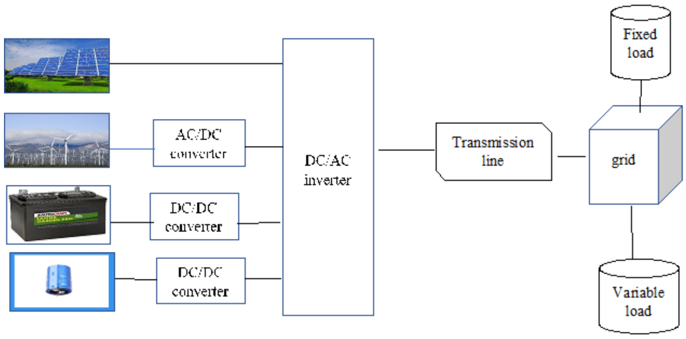

Figure.1. Block Diagram of the system under study

Solar PV panels generate electric power proportional to the solar irradiation, since the generated power is in the form of DC it is coupled to the grid over a DC to AC inverter.

Wind energy conversion systems generates electricity in the form of AC relative to the wind velocity of the area, and to match the frequency of generation it is first converted to DC and then to AC before interconnection with the grid. The intermittent nature of renewable sources is taken care of by providing suitable storage devices which supply power when no power generation takes place in RES. Battery energy storage systems (BESS) is the most widely employed storage device and provide for the constant power variations in the system. To improve the system reliability supercapacitor energy bank is also employed which provides transient and fluctuating power changes owing to its truncated energy concentration [11]. The voltage source converter provides the control for LVRT enhancement by proper switching of inverter. From the inverter AC power is transmitted through transformer to the utility grid.

In the proposed system variable load is also considered in order to get a more real time model to analyse and study the LVRT of hybrid renewable energy systems with fault current restraining function of supercapacitor. The fault current limiter (FCL) limits the prospective fault current without complete disconnection.

III. Proposed Methodology

Electrical networks are often subjected to different types of faults when in operation. Under normal operating conditions the power system and related equipment's operate at nominal voltages and currents. When subjected to a fault, voltage and current values deviates from its nominal values, which causes overcurrent, undervoltage, unbalanced phases and voltage surges. Short circuit faults are the most severe and common types of faults caused due to insulation failure or overloading, leading to variation in operating voltage.

In order to prevent greater damage to power system apparatus, these faults must be cleared within a specified period of time. The protection system does so by isolating the fault area and tripping the generators. But, according to IWGC the generators should remain linked to the system and aid in clearing the fault. The terminology used is low voltage ride through or fault ride through feature of distributed generation. In case of any abnormal condition, the fault current limiting function of supercapacitor effectively reduces the fault current thus enabling the generator to remain coupled to the grid while fault is cleared.

The sources are linked to the grid through an inverter, whose switching is controlled by a controller. The control intention of the inverter is achieved by feedback control using PI controllers [13]. The yielded signals of PI controllers are altered to reference three phase currents. PI controller parameters are given in table 1., it is obtained by trial and error method.

Table 1. PI controller parameters

Parameter	K_{p1}	K_{i1}	K_{p2}	K_{i2}	K_{p3}	K_{i3}
Value	0.55	2500	0.001	0.15	0.8	200

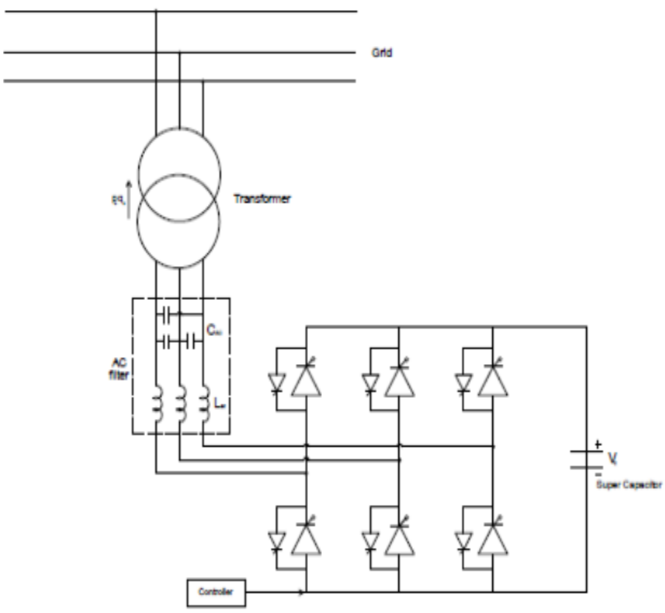

Figure.2. Proposed controller

IV. SIMULATION STUDIES

Study system

Figure 1 shows the block diagram of the system modelled to perform case study. The loads (fixed and variable) in the grid are supplied by renewable sources solar PV and wind turbine generator. Owing to the erratic nature of these sources the system is given a backup by battery and supercapacitor as energy sources. All these sources are connected to the grid through an inverter. The planned technique is realized in MATLAB/Simulink platform and the performances are evaluated.

Case studies

In this section, performance investigation of proposed technique is scrutinized with PV, WT, supercapacitor and battery which are connected to the grid through an inverter. The response of the system to different scenarios is examined with the help of various case studies.

Case 1: Single line to ground fault

A single line to ground fault is applied at t=0.98s with a fault resistance 0.66Ω, in the middle of the tie line and the grid voltage and grid current are examined. From figure 3, we can see the increase in fault current at the instance of fault, also a swell in grid voltage from 0.2s to 0.3s and sag from 0.3s to 0.4s.

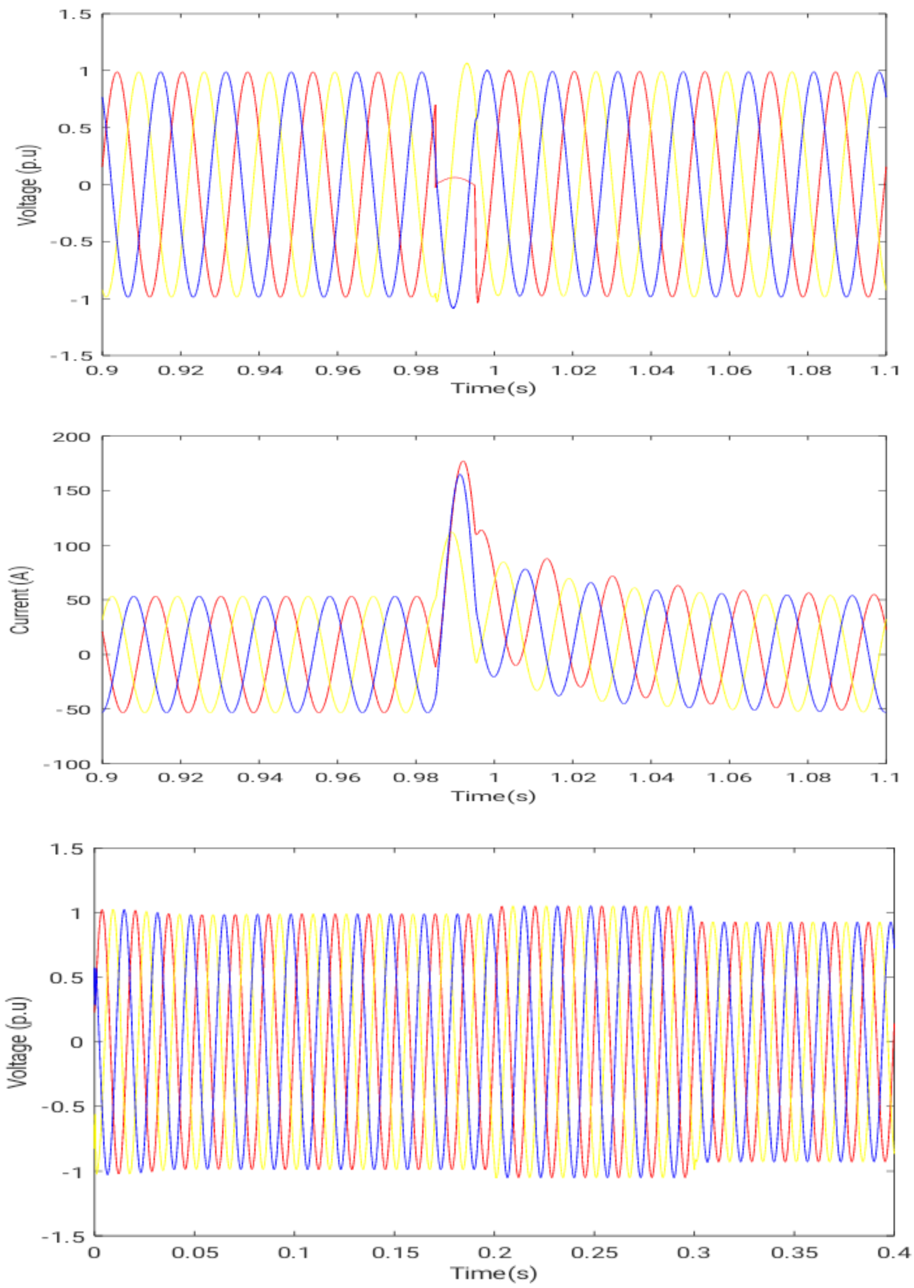

Figure.3. Grid voltage, grid current and grid voltage showing sag and swell in the course of single phase to ground fault without supercapacitor.

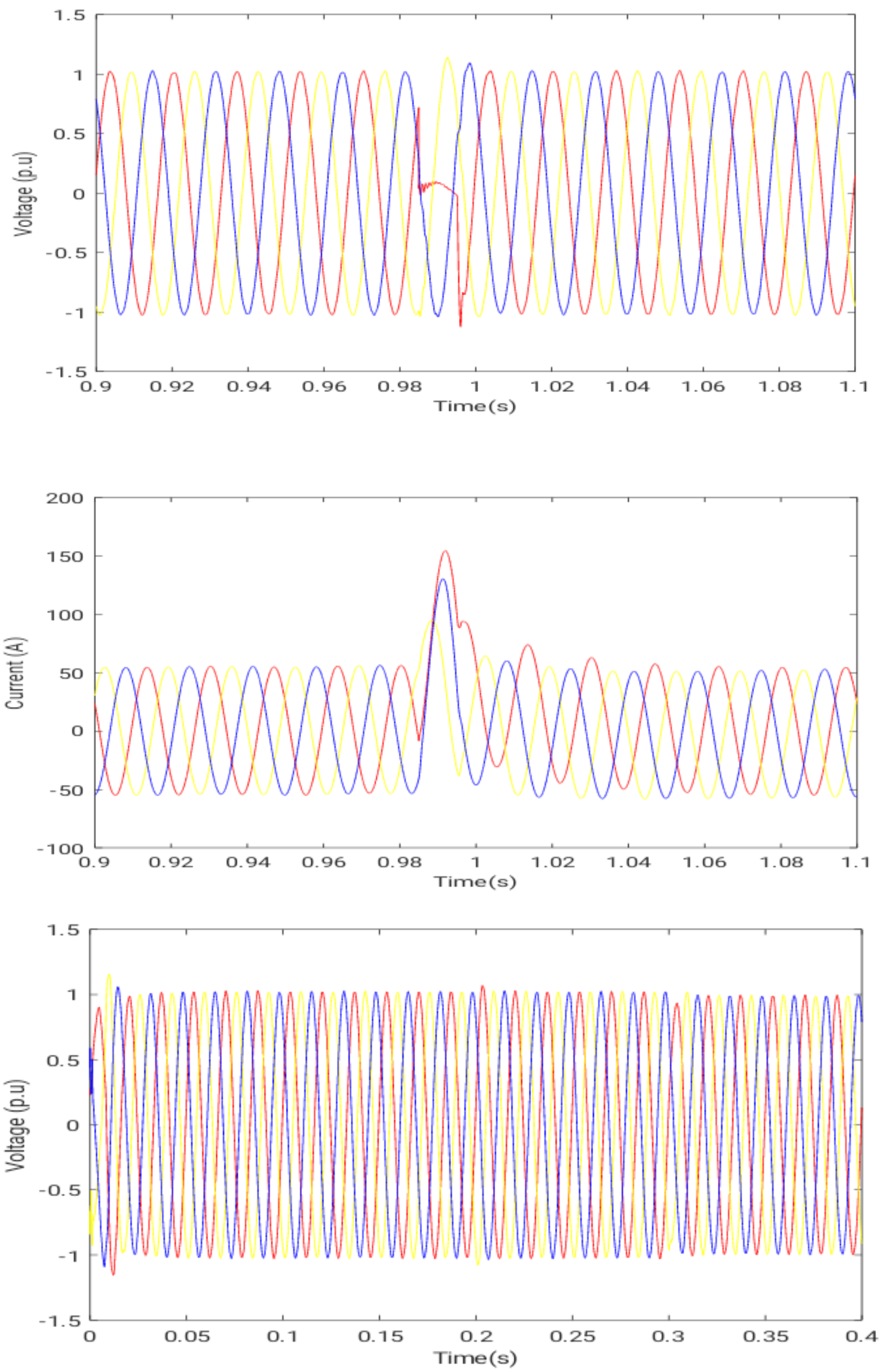

Figure.4. Grid voltage, grid current and grid voltage showing sag and swell during single phase to ground fault with capacitor.

By closely examining figure 4, we can see that there has been a reduction in fault current from 180A to 150A and also the sag and swell in grid voltage is mitigated by adding supercapacitor controls.

Case 2: Double line to ground fault

The system is exposed to double line to ground fault in R and Y phases at t=0.98sec. The waveforms of grid voltage and current is shown in figure 5.

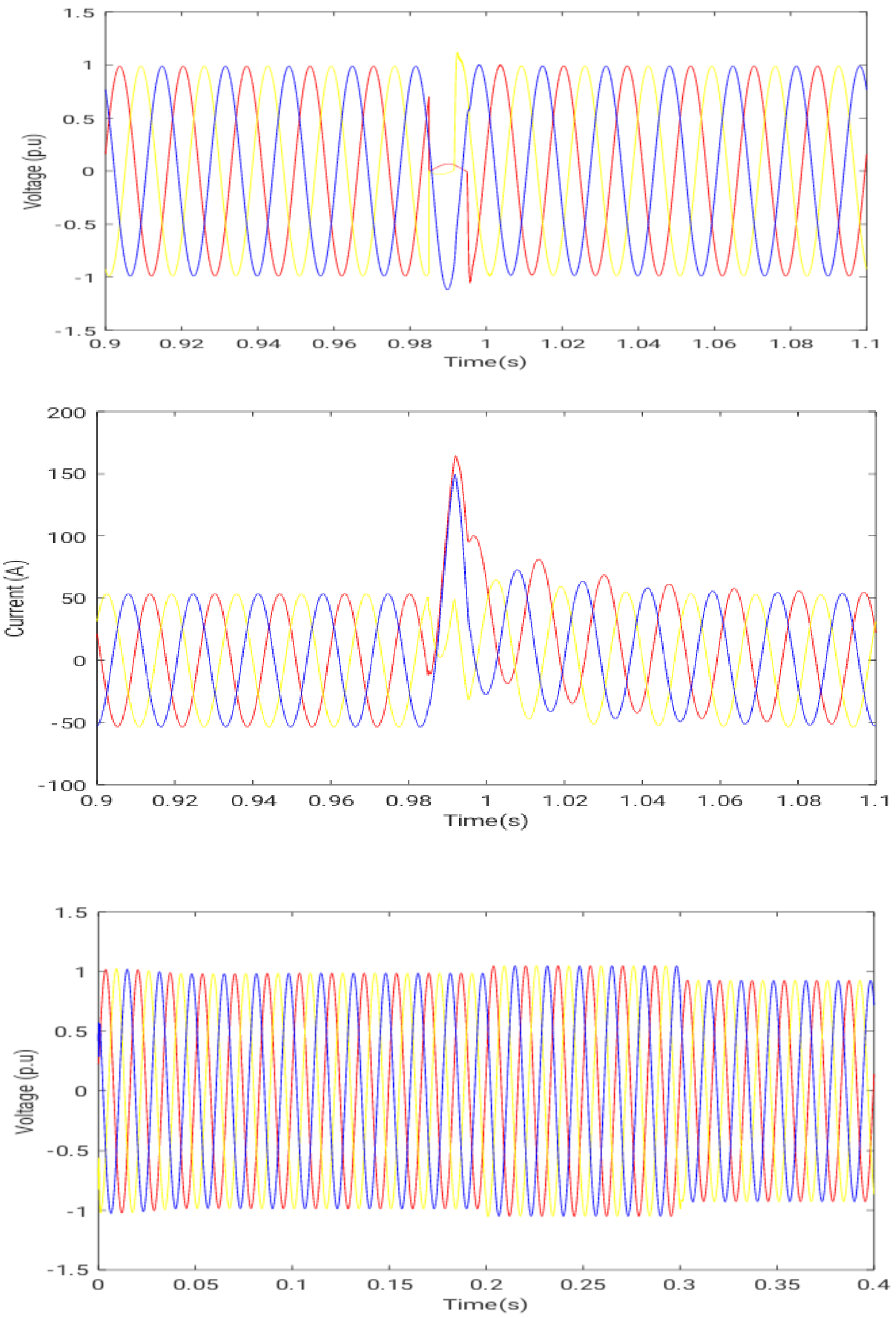

Figure 5. voltage and current waveforms of the grid and grid voltage showing sag and swell with double line to ground fault and without capacitor

Figure 6, shows the change in grid voltage and grid current fluctuations after incorporating supercapacitor in the circuit. Reduction in fault current from180A to 148A proves the addition of supercapacitor reduces the fault current thereby preventing LVRT.

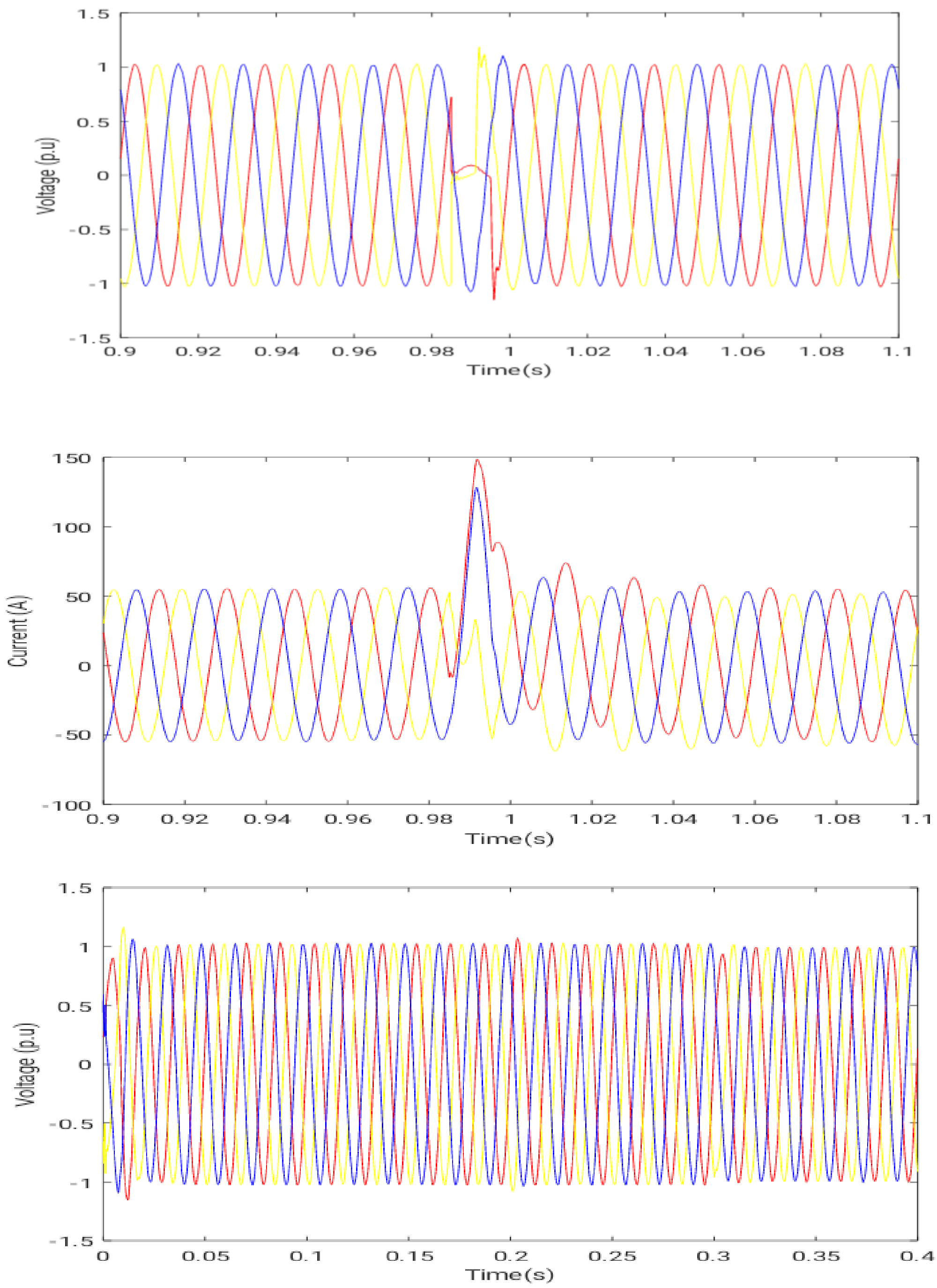

Figure 6. grid voltage, grid current and grid voltage showing sag and swell with double line to ground fault and with capacitor

Case 3: Three phase to ground fault

Three phases to ground fault is applied in the middle of the tie line at t=0.98sec and corresponding waveforms are obtained in figure7. Figure 8 shows the reduction in fault current and subsequent mitigation of fluctuations in grid voltage when supercapacitor is added in the circuit.

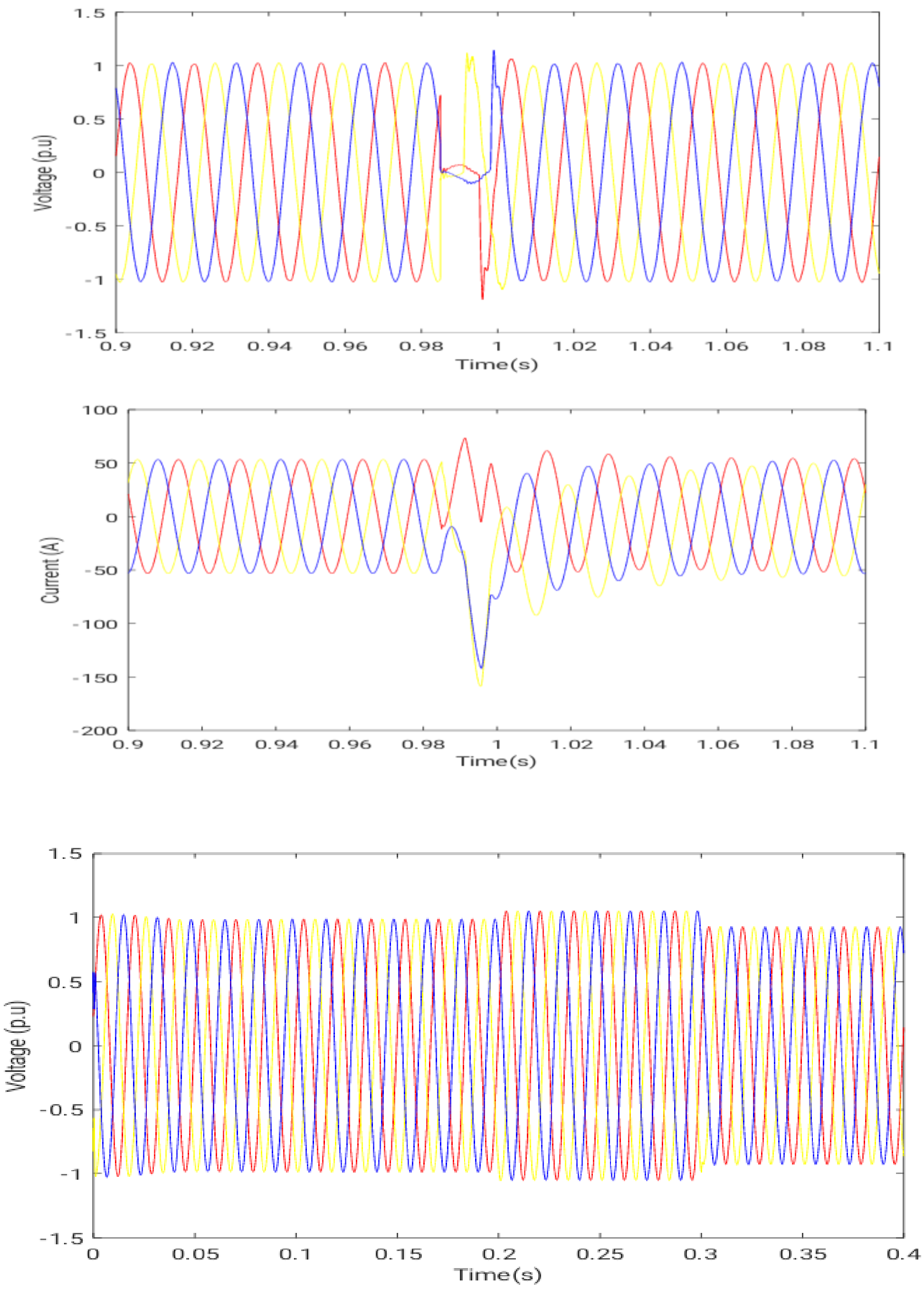

Figure 7. grid voltage, grid current and grid voltage showing sag and swell with three phases to ground fault and without capacitor

January - February 2020
ISSN: 0193 - 4120 Page No. 6289 - 6298

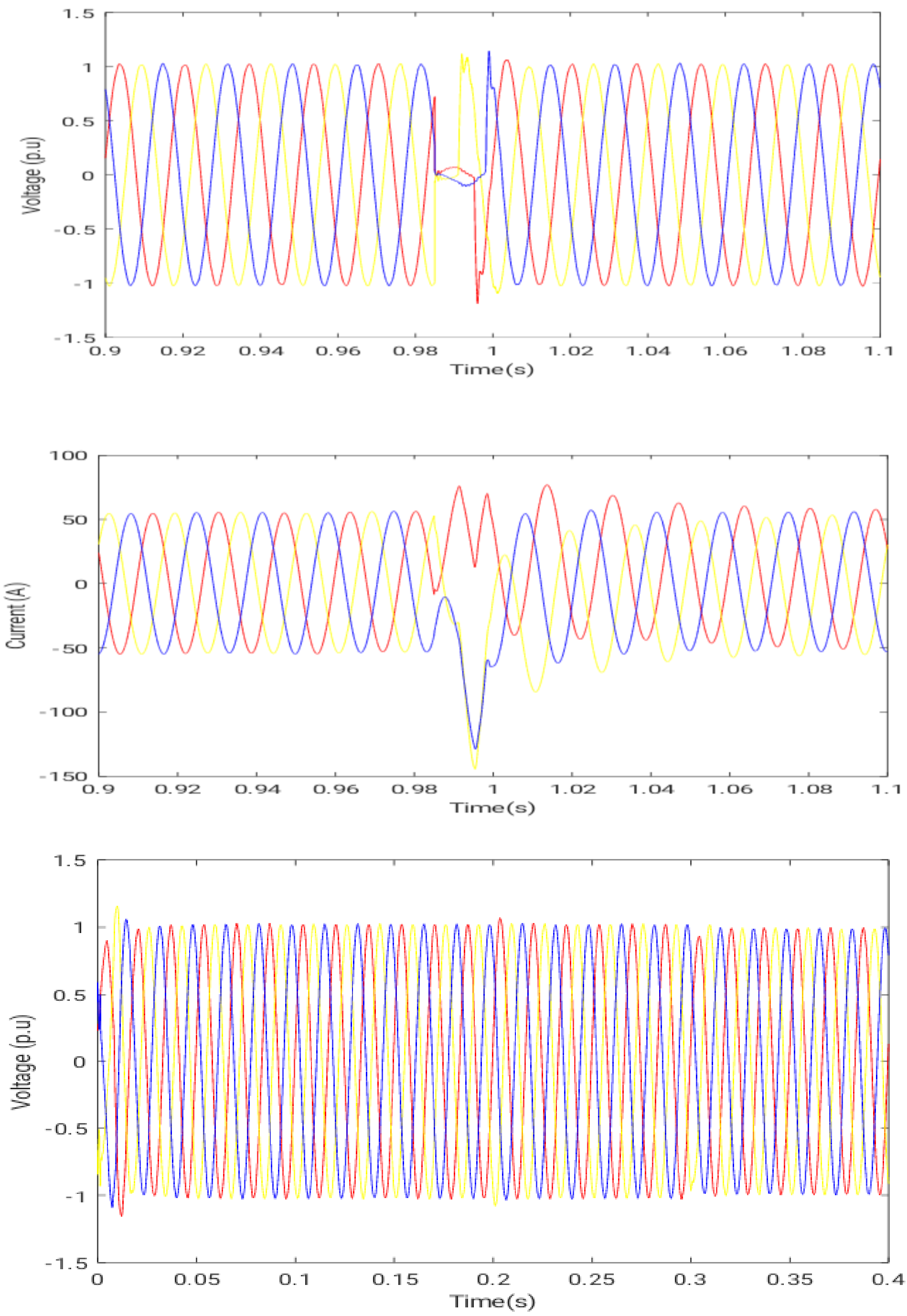

Figure 8. grid voltage, grid current and grid voltage showing sag and swell with three phases to ground fault and with capacitor

V. Conclusion

This paper grants a established control strategy for refining the fault current limiting LVRT capability of three-phase MG system. The obtained results confirm the efficiency of the future control strategy, in compensating the grid with the wanted reactive power in the event of varying abnormal conditions like varying load and fault in the network. The three cases considered for study are the most common and severe faults in power system and the outcomes demonstrates the efficacy of the proposed model. The incorporation of a variable load in the system, helps in giving a practical case where load is always varying. The result shows that the proposed controller is effective in case of varying loads as

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well. Simulation results established the validity of proposed structure and control strategy. Thus PV/ WT together with hybrid energy storage presents a promising choice for action as hybrid AC/DC microgrid.

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