Impact of DG and EV loading on Distribution Network and its Protection using SEL351-S Protection Units

Hassan Zahid Butt, Hamd Ullah, Mehak Asad,
Muhammad Huzaifa Siddique, Muhammad Suhaib
Department of Electrical Engineering
National University of Sciences and Technology, Pakistan
{hzbutt120222, hullah1, mehakasad67, msiddi13, msiddi13}@asu.edu

Qiushi Cui, Yang Weng
School of Electrical, Computer and Energy Engineering
Arizona State University, USA
{qiushi.cui, yang.weng}@asu.edu

***Abstract* - Distributed Generation (DG) systems are gaining considerate importance because it eliminates the need to transmit electrical power over long distances and have the capability to work in an islanded and grid connected mode as well. However, high penetration of DG sources can cause stability and protection issues in the distribution system network in the form of transients in the voltage and current profiles. Another problem being addressed is how Plug-in Electric Vehicles' (PEV) charging from the low-voltage distribution network could impact the distribution system in terms of voltage unbalance and transformer overloading. This paper models a distribution network model and the study is focused on how DG penetration and EV loading can affect the voltage and current profiles. A protection scheme is also proposed using the SEL-351S protection unit. The proposed system is first modelled and tested in MATLAB/Simulink and then verified via experimental results. The results show the effectiveness of the proposed solution.**

Index Terms – distributed generation, protection, electric vehicles, stability, DG penetration

I. Introduction

The modern power system network is moving towards a decentralized topology to lower the transmission power losses and the cost of transmission lines [1]–[3]. Distributed Generation (DG) thus have gained a huge reputation in this domain because of they finish the need to transmit power over long distances and also have the capability to work in an off-grid remote environment as well [4],[5]. In the case of surplus generated power, these sources can supply power and fulfill the reactive power requirements of the grid as well [6]. The use of renewables as DG sources has gained importance because of their ability to generate clean energy, thus lowering the environmental risks [7],[8]. Fig. 1 shows the global growth rate of renewables measured in 2016.

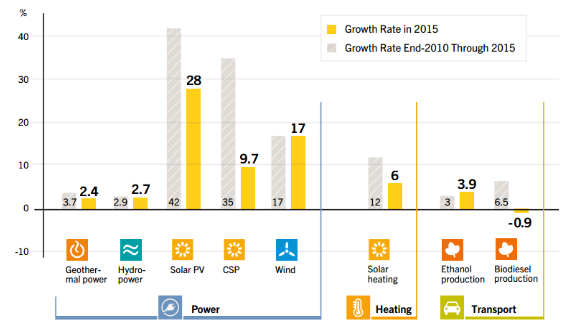

Fig. 1 Global status report of renewble energy sources (source: Renewables 2016, Global Status Report)

The problem with DG sources however is that with their increases penetration in the grid network, the power system loses its inertia, thus making the system more sensitive towards disturbances [9]. Fig. 2 shows that with the increased penetration of DG sources comprising of renewables, the Rate of Change of Frequency (ROCOF) increases when subjected to a disturbance. Another problem that arises with the DG penetration is that the it disturbs the radial power flow of the network that can cause loss of relay coordination and can cause the system to mal-operate [10]. [11] discusses that with the penetration of DG, the fault current also increases that poses greater damage risks to the system.

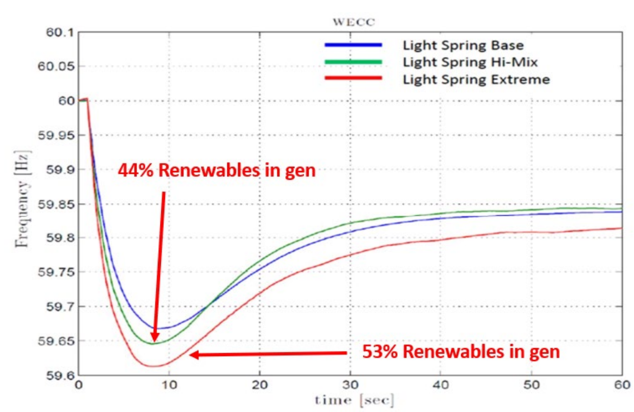

Fig. 2 Lower frequency nadirs with increases DG penetration (source: Western Wind and Solar Integration Study Phase 3)

Many studies have been conducted in the literature to mitigate the negative impacts of DG penetration. [12] discusses the use of ----- (upto [17])

In this paper, an electrical circuit is implemented to mimic a 9-mile long distribution network. DG penetration is done in this model to observe its impacts. Another problem being addresses is how Plug-In Electric Vehicles' (PEV) charging from the low-voltage distribution network could affect the system in terms of voltage unbalance, transformer saturation and power quality issues [12]–[14]. Section 2 describes the proposed system and the protection scheme applied. Section 3 focusses on the MATLAB simulations and section 4 presents the validating experimental results. Finally, section 5 concludes the study.

II. Proposed System

Fig. shows the block diagram of the distribution model implemented. It consists of inductors and resistors to shows the line impedances. A variable transformer is used to create a variable potential difference in the circuit.

Fig. shows the block diagram of the protection scheme implemented.

Shows some mathematical expressions or equations also.

III. Simulation and Results

Fig. shows the MATLAB/Simulink implementation of the distribution network. The simulation is first run to show the normal operating voltages and currents.

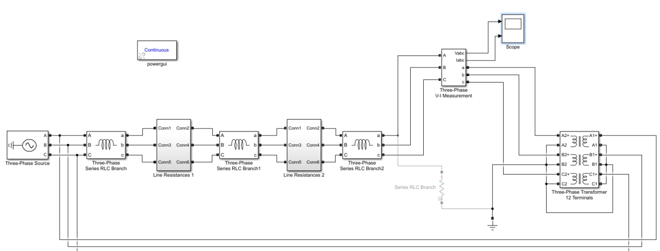

Fig. MATLAB/Simulink implementation of three phase distribution network

The phase voltages and currents without the fault scenario are shown in fig.

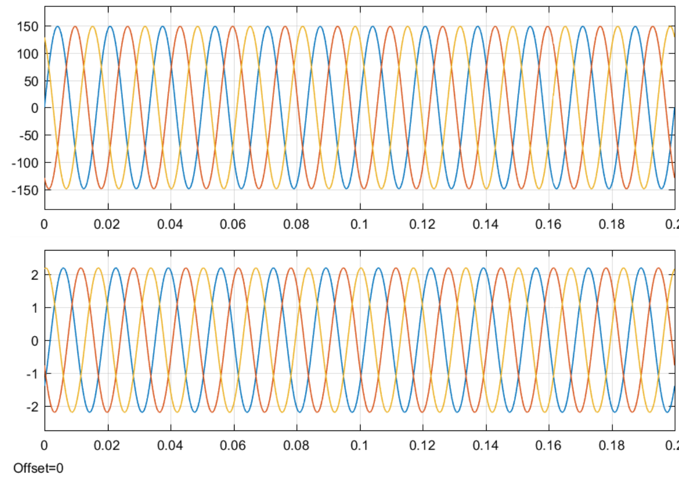

Fig. Phase Voltages and currents without fault conditions

Now, a single line to ground fault is created and the simulation is compared with the experimental results. Fig. shows the software implementation of the circuit with fault and fig. shows the simulation results.

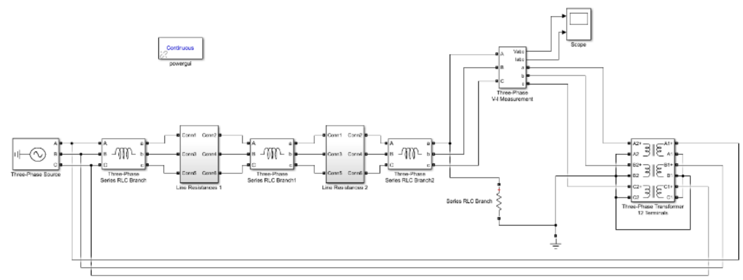

Fig. 4 Software implementation with fault

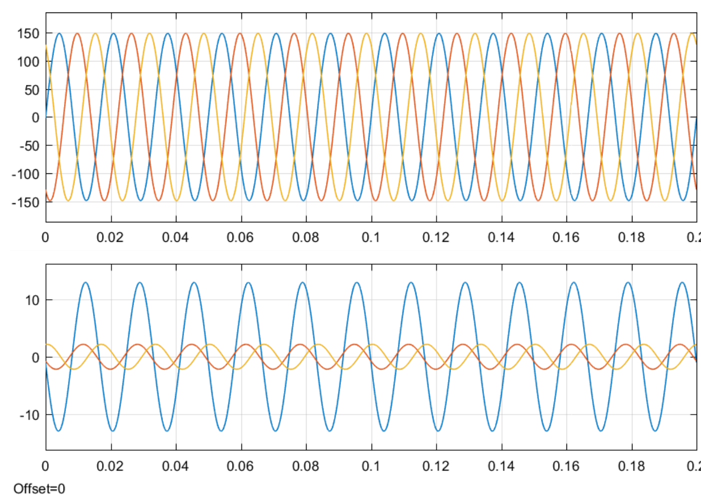

Fig. Phase Voltages and currents with fault conditions

Fig. 5 Phase Voltages and Currents when fault occurred

The differential protection is then implemented for testing and analysing purpose. Two measurement units are connected at either ends of the system that calculates the differences of the currents. If the differences in the phase currents is not equal to zero, it implies a fault has occurred, thus the breaker should be tripped. Fig. 11 shows the protection scheme and fig. 12 shows the normally operating phase voltages and currents.

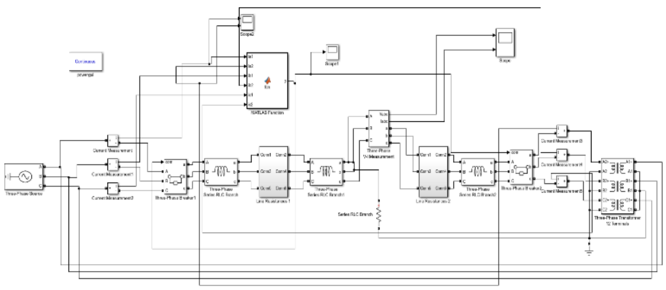

Fig. 11 Implementation of differential protection in distribution network model

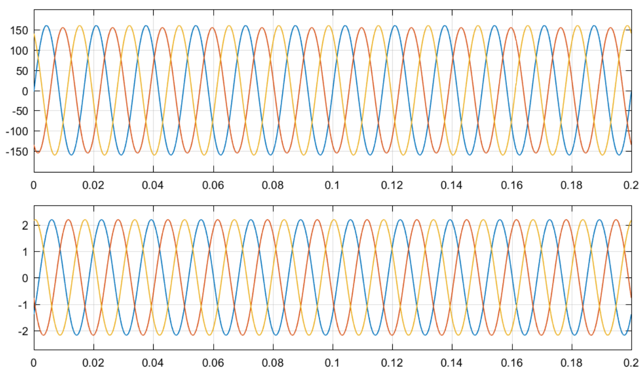

Fig. 12 Normal operating phase voltages and currents

The circuit is then simulated with three types of faults i.e. Single line to ground and double line to ground (Unsymmetrical faults) and triple line to ground fault (symmetrical), and the results are analysed.

Single line to ground fault:

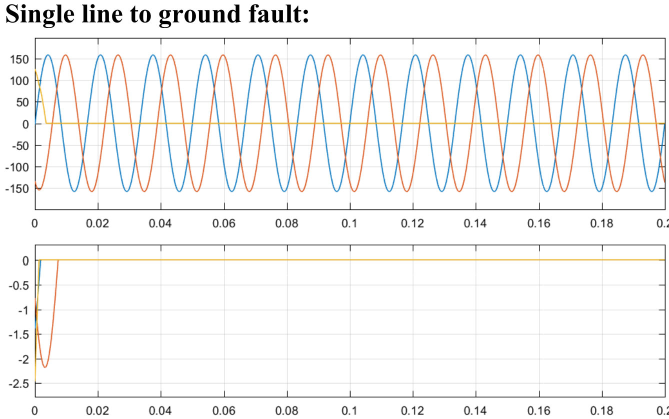

Fig. 13 Phase voltages and currents for single line to ground fault

Double line to ground fault:

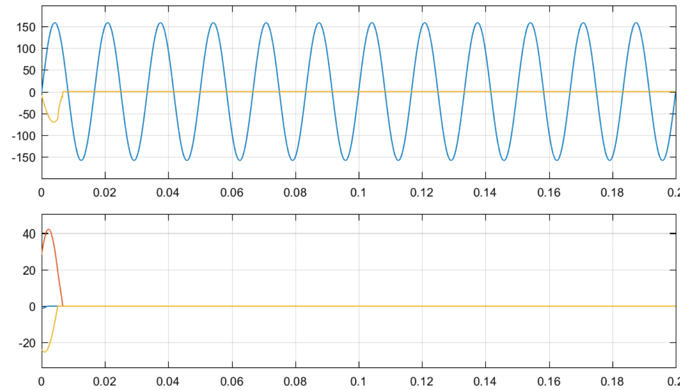

Fig. 14 Phase voltages and currents for double line to ground fault

Triple line to ground fault:

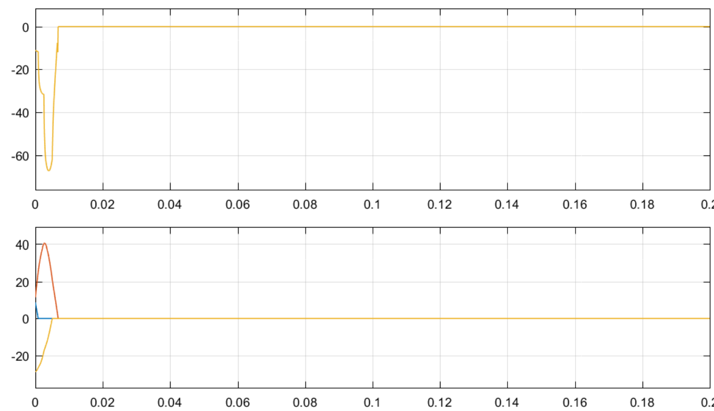

Fig. 15 Phase voltages and currents for triple line to ground fault

The circuit is then simulated with two cases; DG penetration and EV loading. Fig. shows that with both these cases, the differential protection fail to provide protection and thus a better protection scheme needs to be implemented.

IV. Experimental Results

Fig. shows the experimental setup of the distribution network.

V. Conclusion

V1. Future Work (if needed)

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