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Solutions for Voltage Sags During Distributed Generation Anti – Islanding Protection

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Abstract: In this paper, solutions to the problem of voltage sags caused by distributed generators anti-islanding protection are proposed. In a system with both substation and Distributed Generator (DG) supplying in parallel to a load, during any temporary fault condition, the DG will be disconnected from system by anti –islanding protection. After the reclose operation, the whole power has to come from the substation since the DG is no longer present and due to this there is voltage sag at the load end. This problem can seriously affect power quality indices as well as distributed generators reconnection procedure. In this context, this work investigates several potential solutions to be adopted by the utility or the DG owners and presents a thorough evaluation of their main advantages and disadvantages. The presented studies and procedures will guide the utility engineers in the making decision process associated to the choice of reasonable mitigation techniques to this problem. Solutions are simulated using ETAP 12.0 tool and HIL typhoon SCADA software. Certain solutions are simulated by developing a hardware prototype. The results obtained were compared and analysed for the better understanding of the stated solutions.

Keywords: Anti-islanding, Reclosing operation, Voltage sag

I. INTRODUCTION

Distributed Generation (DG) has become more popular worldwide due to deregulations in market, environmental aspects, cost effectiveness and other benefits it can provide to the system operations. DG can be defined as any power source connected to the main distribution system within voltage levels of 100V to 150 kV. Considering the benefits of the DG technologies, the number of DG systems connected has been increasing day by day. Many interconnection guidelines are existing in the practice and the utilities must comply with the above said practices. Anti- islanding protection is one of such existing practices. Anti- islanding protection aims to disconnect all the distributed generators by tripping them at the event any temporary fault occurs at the downstream. Failure to disconnect the generators may lead to serious problems during the islanding operation such as reclosing operation and shock hazards to the operators.
There is an unprecedented consequence for the anti-islanding protection even it prevents the above said electrical damages. When a temporary fault occurs at the downstream of the recloser, the recloser opens and island is formed. As said, the islanding operation is not advisable and with anti-islanding protection, system disconnects all the distributed generators immediately. When the island is reconnected to the system, the Dg's are no longer present and the whole power has to come from the substation. So the power flow from substation through long transmission lines has increased significantly now. This will create voltage sag at the load end. Voltage sag can be defined as the reduction in voltage for 0.1 to 0.9 p.u. for a period between 1 half cycle to one minute in at least one phase of the electrical system. This voltage sag may cause severe problems to the customers such as shutdown of voltage sensitive loads, interruption of voltage- sensitive processes, costs associated with the interruption, low performance of synchronous and induction motors. The voltage sag associated with the anti-islanding protection can violate the power quality (PQ) limits of requirements defined by Information Technology Industry Council curve (ITI curve) and some other prevailing standards. This paper is organized as follows. Section II explains voltage sag problems with some set of indices to characterize the problem. Section III explains various solutions for the problem identified through extensive literature survey. Section IV explains the simulation results of proposed solutions. Analysis and comparisons are included in section V. Main Conclusions are drawn in section VI.

II. PROBLEM DESCRIPTION

The problem of voltage sag during ati islanding can be explained using fig.1. here SUB represents the substation SVR represents step voltage regulator. Active power is indicated with solid line and reactive power with dashed line.

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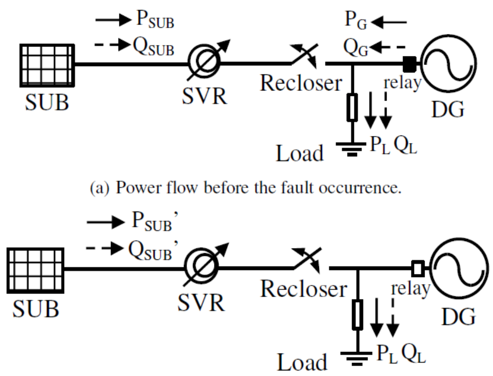

Fig.1. Distribution System

Voltage at the load side is automatically adjusted by changing the taps of SVR automatically. The power flow through the recloser is given by the expression

$$(P_L + jQ_L) - (P_G + jQ_G) = (P_{SUB} + jQ_{SUB}) \quad (1)$$

If any fault is occurred at the load side, recloser will immediately disconnect th DG before reclosing operation by anti-islanding protection. If the fault is not persisting, the recloser will reclose and the load is connected back to the system. Now the power flow through the recloser is increased and is given by the expression

$$(P_L + jQ_L) = (P_{SUB} + jQ_{SUB}) \quad (2)$$

With this increased power flow, the current through the long transmission line is increased and it leads to voltage sag at the load side. Now, the step voltage regulator is adjusted itself to regulate the voltage by changing its tap position. But this operation requires some time duration for the complete operation as shown below

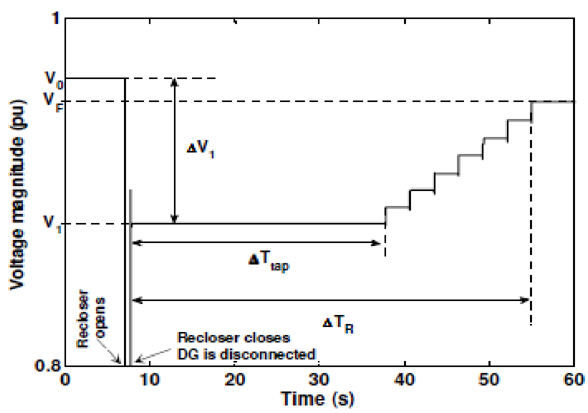

Fig.2. Voltage vs Time of SVR operation

Three parameters are defined to characterize the above said voltage sag problem. 1) ΔV_1 – First voltage sag, which is defined as the voltage sag immediately after the recloser operation. 2) ΔT_{tap} – Time delay for the first tap movement. 3) ΔT_R – Total time delay for the voltage to recover to steady state.

III. SOLUTIONS IDENTIFIED

After extensive Literature review, the following solutions are identified for the above said voltage sag problem caused by DG anti-islanding protection.

- Non – Sequential tap changing of SVR
- Load curtailment
- Capacitor addition
- Centralized control of regulation devices using SCADA
- PV control mode of DG

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a) Non – Sequential tap changing of SVR: In the base case defined the taps of SVR is adjusted in a step by step manner, for which the initial tap change takes around 30 Sec, so as to avoid the mis-operation. Each of the remaining step takes 3 sec. So for an voltage adjustment with 6 tap changes, ΔT_R is around 48 sec {30 + (6x3 sec)}. In non-sequential tap change of SVR method, the initial voltage sag (ΔV_1) is measured. Then the number of tap changes required is automatically calculated and the tap of SVR is adjusted in a single step. This will reduce the total voltage sag duration (ΔT_R) to 30 Sec from 48 Sec.

b) Load curtailment - As seen in equation (3) below, the voltage at the load end can be increased by reducing the load active power P_L and load reactive power Q_L. Non-priority loads are identified for the system. At the event of anti-islanding operation, some of the non-priority loads are shed to improve the voltage at load end.

$$V_L \approx V_S + \frac{R \cdot (P_G - P_L) + X \cdot (Q_G - Q_L)}{V_L} \tag{3}$$

c) Capacitor addition – Capacitors in power system are usually used to improve the power factor and for the reactive power compensation. Capacitors of required VA compensation are added at the event of anti- islanding. The position and rating of capacitors are identified by conducting different load flow analysis.

d) Centralized control of regulation devices using SCADA - The idea of this technique is to adjust various voltage regulation devices using some centralized controls such as SCADA(Supervisory Control And Data Acquisition) or DMS (Distributed management System) so that no voltage violation is occurred at the time of anti-islanding. Extensive Load flow analysis shall be done before to find out the load curtailment, transformer tap positions and capacitor insertion at various faulty conditions.

e) PV control mode of DG -This is a theoretically important solution and no simulation is done by the authors to prove the accuracy of this solution. Here the DG control mode is changed from PQ (Active and Reactive) mode to PV (active power and voltage magnitude) control mode. Here the voltage at the Point of Common Coupling (PCC) is kept constant and equal to the voltage calculated at the same bus, without the DG.

IV. SIMULATION RESULTS

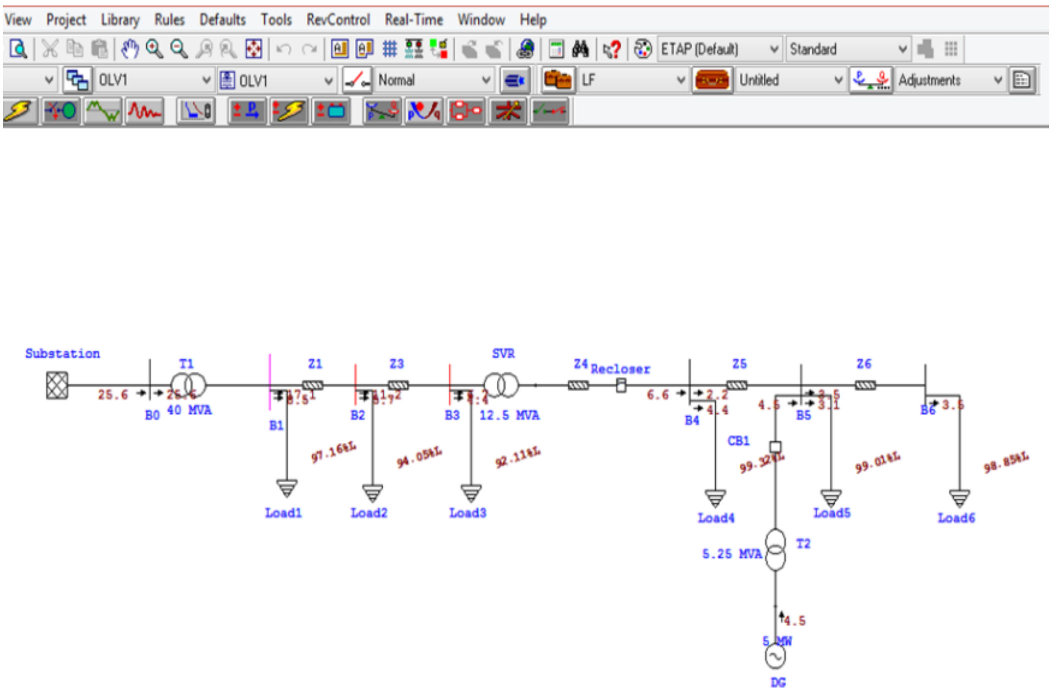

Fig 3. Normal operation

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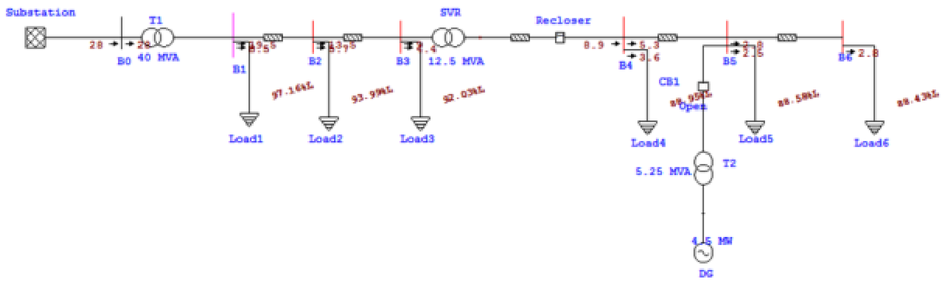

Fig 4. After reclosing operation (DG disconnected)

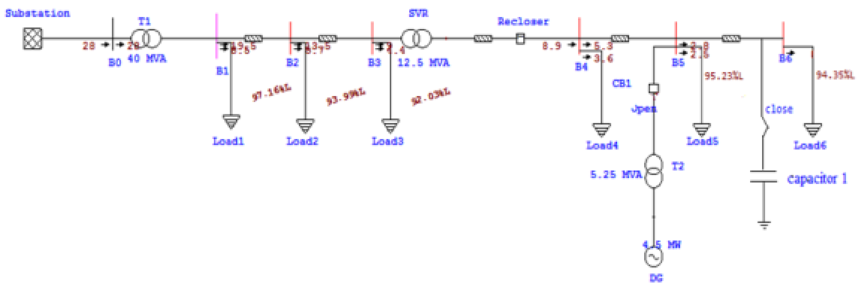

Fig 5. Capacitor switching

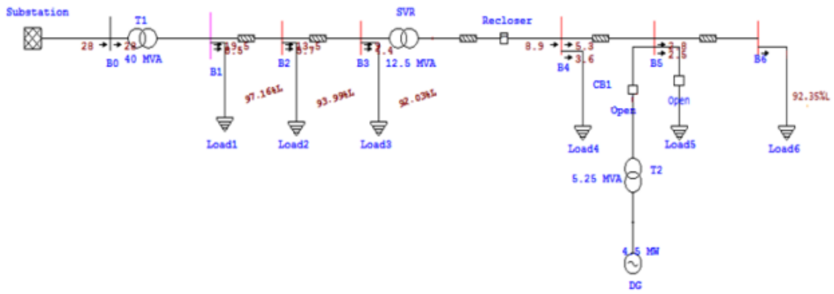

Fig 6. Load trip

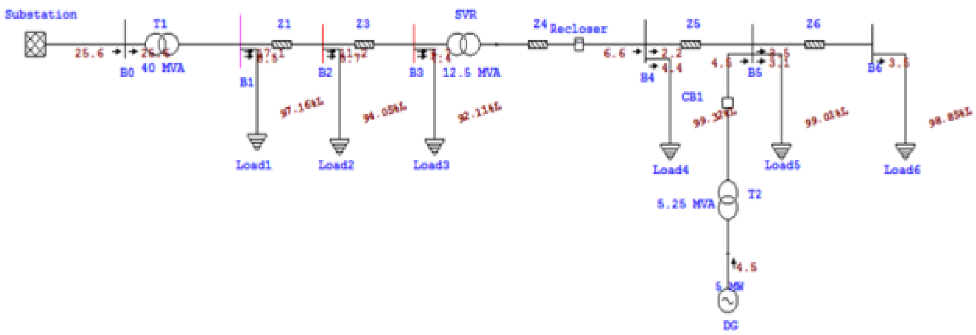

Fig 7. Non-sequential tap change of transformer

The results obtained from above simulations are tabulated below.

	Base case	Capacitor	Load trip	Non seq
ΔV_1(pu)	10.42	4.53	6.5	0
ΔT_R(S)	48	39	36	33

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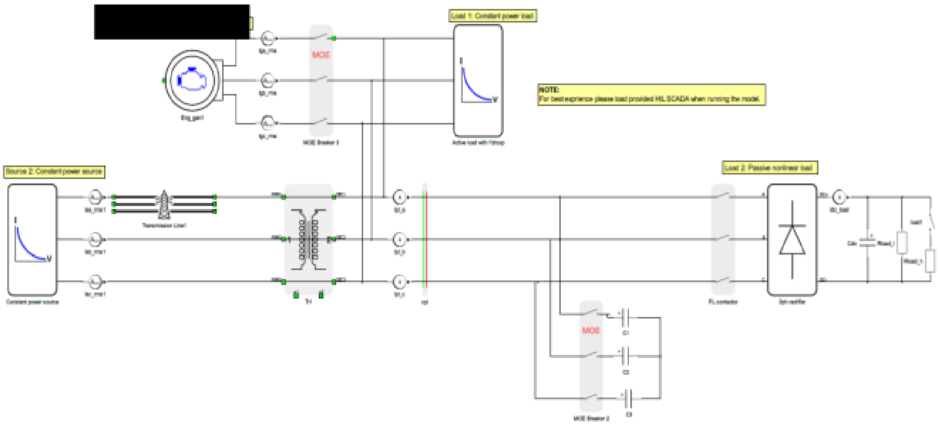

Fig 8. CCVRD SCADA using HIL Typhoon.

Centralized control of all the voltage regulation devices is simulated in HIL Typhoon SCADA software and the results obtained are tabulated under.

	Base case	CCVRD
ΔV_1 (pu)	10.42	5.31
ΔT_R (S)	30	12
ΔT_{tap1} (S)	48	15

A prototype is developed to scale down the existing system to a smaller one to simulate out the results. Block diagram and hardware realization of the same are as shown in fig 9. and fig.10 respectively.

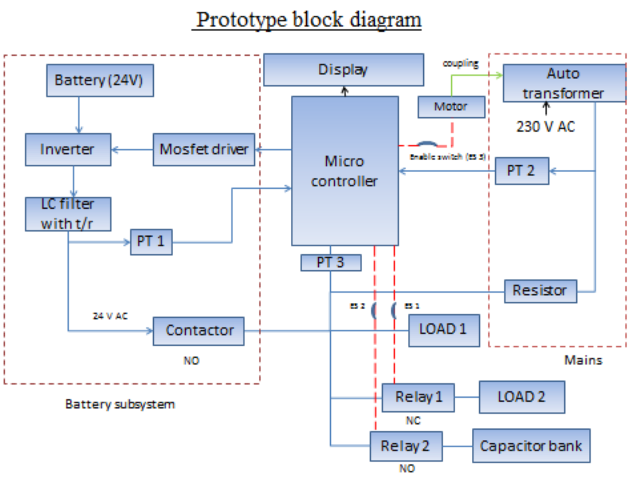

Fig.9 Hardware block diagram

Fig.10 Prototype realization

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CONCLUSIONS

This paper includes the description of recently identified voltage sag issue in DG anti-islanding protection. Three parameters to characterize the phenomenon are described. Along with the proposal of potential solutions, each solution except the DG PV control mode is simulated to verify the results. Each solution has its own benefits and suitability of each solution depends according to the system where it is to be implemented. This work can be used to guide the utility engineers in the making decision process to this power quality concern.

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