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Reducing the impact of DG on distribution networks protection with reverse power relay

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Abstract

The assimilation of distributed sources in to existing distribution networks (DN's) will bring up the several technical, economical and regulatory questions. Conventional distribution system is radial in nature, characterized by a single source feeding a network of downstream feeders. Therefore the voltages decrease towards the end of the feeder from the source, The incidence of distributed generators (DG) in the distribution networks alter the radial nature of distribution, causes the power flow in reverse direction in the event of DG is added in a system, or any fault in the feeding source/end, the DG exceed the local load, that is, towards the high voltage grid, it causes the existing protection system fails to protect the distribution networks against these changes.

To solve this problem reverse power relay (RPR) is proposed to protect the system voltage fluctuations, power reversals condition. The proposed Reverse power relay is a directional power relay it monitor the power flow from a generator (centralized) running in parallel with another generator (DG) or the utility. The reverse power relay prevents a reverse power in the network by disconnect the DG from the distribution network under faulted condition. It also estimates the reverse power and proposes corresponding adjustment value to provide solution to protect distribution network as per the relay settings and distribution system changing scenario. The simulations have been performed using mat lab/simulink.

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Keywords: ***Distributed generation; distributed networks; radial networks; protection system; power reversals; Reverse power relay.***

1. Introduction

Photovoltaic cells power generation as a distributed generation

A) Basics of Photovoltaic cells based power generation

The virtue of semiconductor materials which is present in a photovoltaic (PV) cell is unswervingly converts into direct current electricity from solar energy. When sunlight shines on an individual PV cell, the energy that the cell absorbs from the sunlight is transferred to electrons in the atoms of the semiconductor material. This excited electrons creates the electrical current in the circuit, generates electricity. PV cells are connected in series (current generation) and in parallel (voltage generation) to one another to form PV modules, the capacities of PV modules are depends on their geometry. Interfaced with a set of additional application-dependent system components (i.e. includes power conditioning unit used to make ready to inject in to the grid from available dc current), form a PV system.

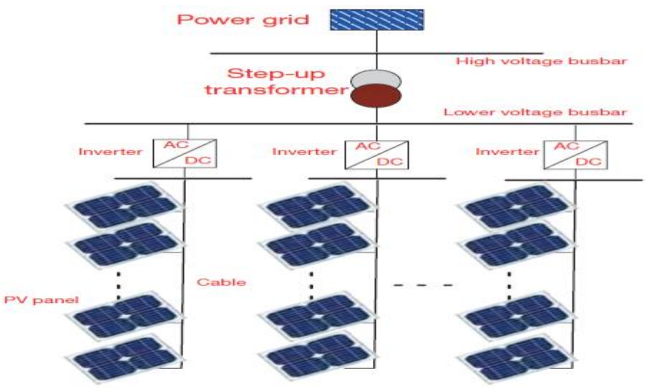

Figure:1.The structure diagram of a PV power station

2) Characteristics of PV power generation

The basic apparatus of PV systems is inverter. DC output fed from PV systems is altered into AC by inverters. The efficacy in integration of PV based Distributed Generation (DG) to the grid will rely on performance of the inverter. in present scenario inverters have flexible active and reactive power control capabilities along with low voltage ride through (LVRT),PV power generation (other than concentrating PV) facilitates the multi functionalities advantage that it used direct sunlight and the diffuse component of sunlight to generate electricity also , which allows its effective exploitation in maximum regions. Compared to wind power generation, PV power generation is less exigent for grid integration because sunlight is more predictable than wind.

Distributed Generation can eliminate requirement of up gradation of transmission lines to enhance electrical power up to some extent. and strengthens the remote power plants. For conventional radial feeders, without any DG, the power flows only radial nature in one direction from the feeding grid towards the loads. Therefore the voltages decrease towards the end of the feeder. the instant at which DG is added to system, in the event the DG exceed the local load and power flows (Bidirectional) reverse direction, that is, towards the high voltage grid. Hence, the power flow can either be from the grid toward loads, or vice versa. Hence, the conventional voltage control systems and protections might be in appropriate when we have DG. Previous research results have shown that DG could have significant impacts on distribution system protection, where DG integrated in to the distribution network leads to great changes in configuration and big task for its control and protection system capacity[1],

Min Dai, Mohammad N. Marwali, Jin-Woo Jung, and Ali Keyhani [2] have presented solution to the power flow control problem of a grid-connected single DG unit. the proposed approach combines voltage regulation plus harmonic minimization under island mode and decoupled P and Q control under grid-connected mode with a nonlinear local load. However the presented techniques are not providing the protection against the faults/ sudden reduction of faults with the presence of Distributed Generation sources.

In this paper, a new solution to the reverse power flow control by reverse power relay (RPR) of a grid-connected single DG unit is proposed. The proposed approach combines discrete Pulse Width Modulation (PWM) generator, discrete Proportional Integral controller (PIC) and discrete 3-phase sequence analyzers are connected to 3-phase circuit breaker. When DG interpreted in to the network i) if DG capacity greater compare to local load, or ii) in the event of fault the injected current, active power(P) and Reactive power(Q) will fed back in to the network. This will alter the existing protection strategy. Results miss-coordination and if in case penetration levels are furtherly added it leads major damage to the distribution network.

2. Cause and estimation of power reverse in distribution network

2.1. ***Power gets reversed due to***

The power gets reversed during synchronization process. If the frequency of the photovoltaic cells based Distributed generation (DG) is differs the bus bar frequency and the 3-phase circuit breaker is closed, power will flow from the bus bar to the DG source. Hence, during synchronization (forward), frequency of the incoming DG is kept slightly higher than that of the bus bar.

by the integration of PV Cells based distributed generation to grid, power flows and voltages in the networks are determined by the merge of centralized and distributed generators as well as the load. With significant levels of DG on feeders, localized overvoltage can occur, and the voltage at the load end may be greater than the voltage on the normal supply side of the line – this is known as the voltage rise and can result in reverse power flow.

The most often technical impact of reverse power flow is due to network protection devices activation these are designed to stop ‘upstream’ current flow only. Voltage regulators can also get destabilization’ control systems - because they are not designed for both forward and reverse power flow. In addition to having negative impacts on end-use equipment, voltage rise can have negative customer equity impacts for system owners towards the end of the line as the voltage rise will be greater at that point.

3. Estimation of reverse power magnitude in the distribution network

Active power of the generator in kW = P_{GEN} [kW]

S_{GEN} computed from the relation $P_{GEN} = S_{GEN} \cos \phi$

For 4 wire system

$P_{R1} = (\sqrt{3}) \times I_N \times (\sqrt{3}) \times V_N \times Ni \times Nv$ and For 3 wire system $P_{R2} = (\sqrt{3}) \times I_N \times V_N \times Ni \times Nv$

where

I_N Nominal current of the relay, V_N Nominal voltage of the relay

Ni Ratio of the current transformer, Nv is Ratio of the voltage transformer

If P_{REV} [%] is the desired reverse-power value in % referring to the active power of the generator, then the value to be adjusted on the relay is calculated as per following formula

$$\text{Adjustment value in \%} = \frac{P_{GEN}\,[\text{kW}]}{P_{R1}\,[\text{kW}]} \times P_{REV}\,[\%]$$

3.1. Flow chart analysis for reverse power mitigation

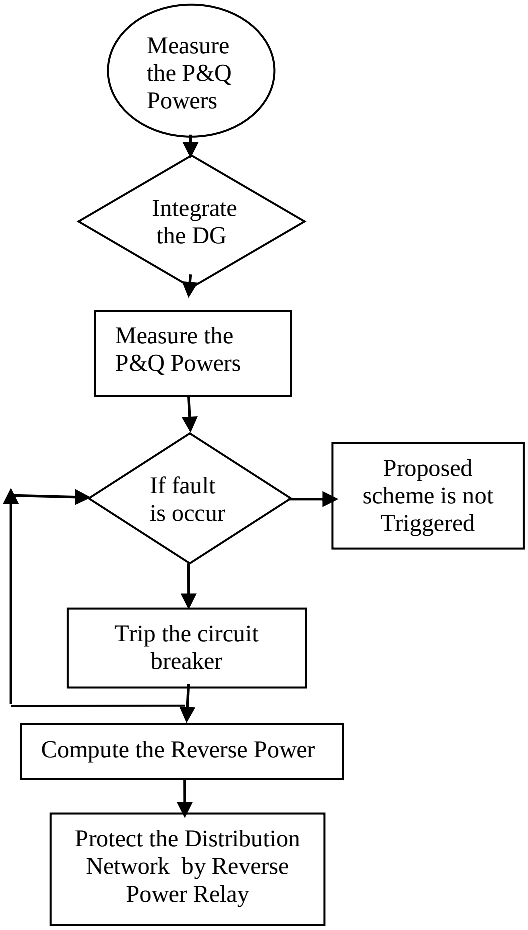

Figure : 2. flowchart analysis

4. Proposed solution for reversed power in distribution networks.

Reverse power relay is a directional power relay that is used to monitor the power from a distributed generator which is running in parallel with another generator or the utility. The function of the reverse power relay is to prevent a reverse power condition in which power flows from the bus bar to the generators. This condition is occurs in the event fault in the network.

The increasing levels of penetration of distributed generators (DG's), either renewable or gas-fired will cause the distribution grids to operate in unconventional conditions. The flow of active or reactive power may become reversed [3] in certain realistic situations such as sunny weekday time in residential areas with high penetration of photovoltaic panels. Active participation of future distribution level power electronics in reactive power compensation may also lead to the local reversal of reactive power flows. These kind of operating conditions are not common to existing power grids, but may become more common in the future and may also have a serious effect on the overall voltage stability of the system. The out put from the PV panel is given to the univerasal bridge where it needs to converts DC-AC, to enhance the output again fed to transformer from the secondary of a transformer directly given to the Reverse power relay(RPR).

4.1.Operation of Reverse Power Relay

PV system ↕ Distribution Transformer ↕

Discrete PWM Generator	*Discrete PI Controller*	*Discrete 3-Phase Sequence Analyzer*	*3-Phase Circuit Breaker*

Figure:3.Block diagrame of Reverse power relay

The function of protective relaying is to cause the prompt removal from service of any element of a power system when it suffers a short circuit, or when it starts to operate in any abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system. The relaying equipment is aided in this task by circuit breakers that are capable of disconnecting the faulty element when they are called upon to do so by the relaying equipment.

Reverse Power Relay consists of discrete PWM generator to generate voltages should have the same frequency that of distribution network, discrete PI controller has to control the mangnitude and frequencies to meet the grid critera and discrete sequence analyzer will compare the signals fed from the PI controller in two different aspects i.e. i) magnitude ii) phase angle if two parameters are within in the limits of a normal operation of a network it will sends the signals to the 3-phase circuit breaker(C.B) to close the contacts or else it will gives the signals to open the(C.B) breaker contacts to disconnect the PV system from the distribution network. If fault is occure to the network suddenly load is reduced in this condition power gets reversed in the network,it leads to miss-coordination of protective devices connected in the network. In this condition RPR will sense the signals and sensed sgnals are transfers to the circuit breaker, it opens the contacts and disconnect the DG from the network and it prevents the above stated protection problems.

5. Simulation results

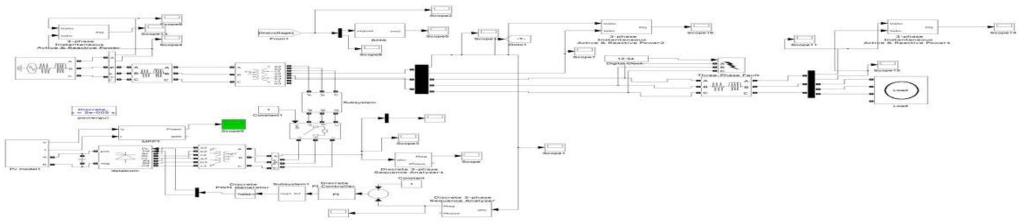

Figure:4. Reverse power relay interfaced to distribution network

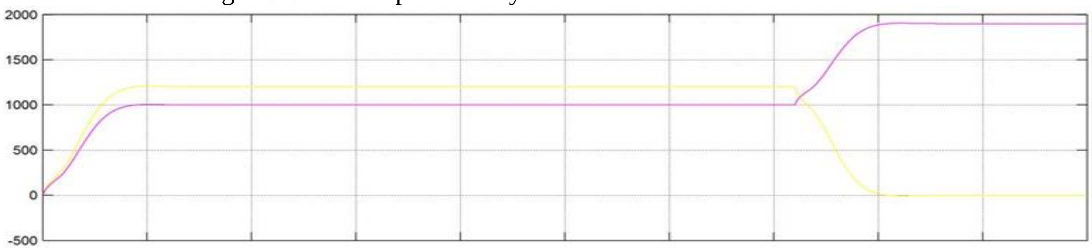

Figure:5.Active power (P) and Reactive Powers (Q) at Grid with DG

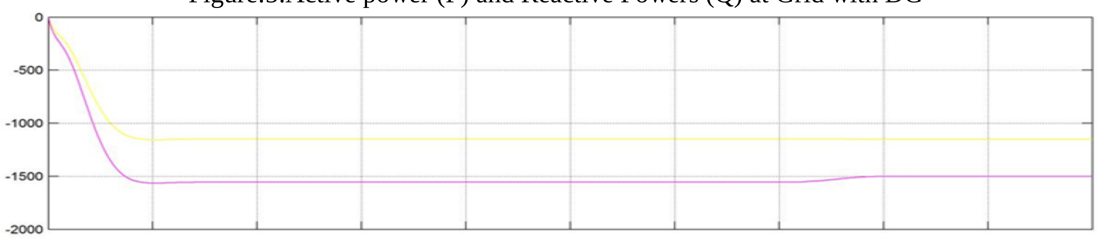

Figure:6.Negative Active power (P) and Reactive Powers (Q) at Grid due to power reversals caused by the fault

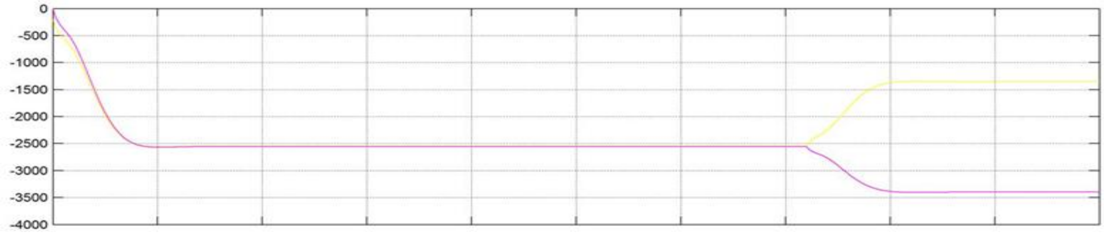

Figure:7.Active power (P) and Reactive Powers (Q) at Grid with DG after clearing the fault

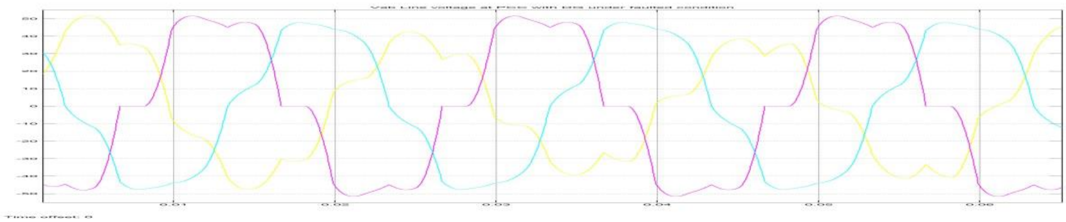

Figure:8. V_{ab} line voltage at PCC with DG under faulted condition

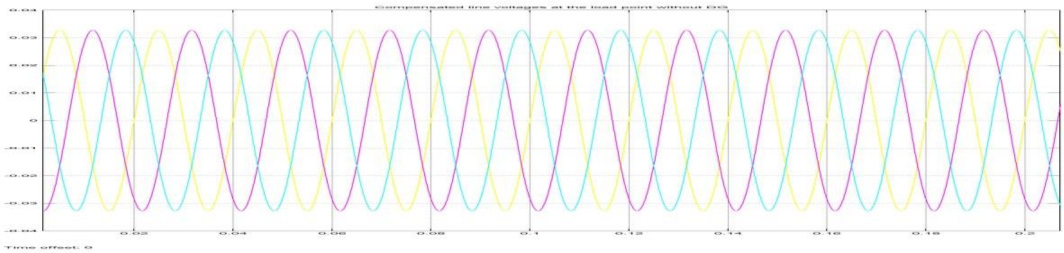

Figure: 9. Compensated line voltages at the load point without DG

6. Conclusion

This paper has presented a reverse power flow control approach for a single distributed generation unit connected to utility grid with a nonlinear local load in the event of fault or sudden diminution of load.The proposed (Reverse Power Relay) control technique combines discrete PWM generator, discrete PI controller and discrete 3 Phase sequence analyzer for sensing the abnormal conditions raised in the network due to faults/external disturbances. Simulation results under various scenarios have demonstrated the effectiveness of the proposed technique prevents the reverse power flow which interns not causes the miss-coordination between protecting devices in the line.

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