SAGS/SWELL COMPENSATION BASED ON VOLTAGE CONTROLLED DISTRIBUTED ENERGY RESOURCES (VC-DER)

1POONAM PATIL, 2ASHA SHENDE

1,2Department of Electrical Engineering, G.H.Raisoni College of Engineering & Technology, Wagholi, Pune
Email: 1poonampatil510@gmail.com, 2ashashende@gmail.com

Abstract - This paper shows compensation techniques of the power quality issues like sags/swells, harmonics and its severe impact on non linear loads or sensitive loads. The Distributed Energy Resources (DER) has become popular as a cost effective solution for the protection of sensitive loads against quality issues. Some power quality disturbances come in electrical systems are voltage sag, swell, notch, spike and transients etc. The voltage sag and swell is very rigorous problem for an industrial customer which needs urgent attention for its compensation. The proposed control scheme is simple to design. The performance of the proposed method can verify with MATLAB/SIMULINK method.

Keywords - Power Quality, Voltage Sag/swell, Distributed Energy Resources (DER), Control Strategy, sensitive load.

I. INTRODUCTION

Power Quality problem involves various disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions. Voltage sag is defined as an drop in rms voltage. It can comes at any instant of time, with amplitudes ranging from 10 – 90% and for a duration of half a cycle to one minute. On the other hand, a swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min. Voltage swells are not as important as voltage sags because they are less common in distribution systems [1][3][10].

Voltage sag and swell are the reason to fail sensitive equipments, or shutdown, as well as create a large current unbalance that could blow fuses or trip breakers. These effects can be very luxurious for the customer, ranging from minor quality variations to production downtime and equipment damage [1]. Voltage sags and swells can mitigated with different methods, but the use of a custom Power device is considered to be the most efficient and economical method [2]. Switching off a large inductive load energizing a large capacitor bank is a typical system event that causes swells. Whereas sag occurred during presence of fault and starting of induction motor. This paper introduces Distributed Energy Resources and its operating principle for sag/swell mitigation with the help of dqo transformation [5]. Finally, MATLAB/SIMULINK model presented the results of proposed control method of DER.

II. CONFIGURATION OF DER

Distributed Energy Resources is a series connected device designed to maintain a constant RMS voltage value across a sensitive load [4]. The VC-DER consists of:

a) an injection / series transformer
b) a harmonic filter,
c) a Voltage Source Converter (VSC),
d) an energy storage
e) a control system

The main function of a DER is the protection of sensitive loads against voltage sags/swells coming from the network. Therefore as shown in Figure 1, the DER is located near to sensitive loads. If a fault occurs on load side at any lines, DER inserts series voltage $V_{DER}$ and compensates load voltage to pre fault value. The brief amplitudes of the three injected phase voltages are controlled such as to remove any destructive effects of a bus fault to the load voltage $V_L$. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter unit and injected on the medium voltage level through the booster/injection transformer. The DER works independently of the type of fault or any event that happens in the system.

![DER general configuration](image)

Fig.1. DER general configuration

For most practical cases, a more economical design can be achieved by only compensating the positive and negative sequence components of the voltage disturbance seen at the input of the DER. This option is sensible because for a typical distribution bus arrangement, the zero sequence part of a disturbance will not pass through the step down
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transformer because of infinite impedance for this component. The DER has two modes of operation which are: standby mode and boost mode. In standby mode \( (V_{\text{DER}} = 0) \), low voltage winding of the booster transformer’s is shorted through the converter. No switching of semiconductors occurs in this mode of operation, because the individual converter legs are triggered such as to begin a short-circuit path for the transformer connection. Therefore, only the comparatively low conduction losses of the semiconductors in this current loop contribute to the losses. The DER will be most of the time in this mode. In boost mode \( (V_{\text{DER}} > 0) \), the DER is injecting a compensation voltage through the booster transformer during detection of a supply voltage disturbance. Figure 2 shows the equivalent circuit of the DER.

![Fig.2. Equivalent circuit diagram of DER](image)

### III. PROPOSED METHOD

The proposed DER is designed using MATLAB/SIMULINK, where the outputs of a three-phase half-bridge inverter are connected to point of common coupling via connected series transformer [4][12]. Once a voltage disturbance occurs, with the aid of dqo transformation based control scheme [5], the inverter output can be injected in phase with the incoming ac source while the load is maintained constant. Output of inverter is installed with capacitors and inductors for a filtering purpose. The control scheme for the proposed system is based on the comparison of a reference voltage and the measured terminal voltage at PCC \( (V_a, V_b, V_c) \). The voltage sags is detected when the supply drops from the reference value whereas voltage swells is detected when supply voltage increases from the reference value. The error signal is used as a modulation signal that allows to generate a commutation pattern for the power switches (IGBT’s) constituting the voltage source converter as per pulse width modulation (PWM) technique [6-9].

![Fig.3. Block diagram for sag/swell compensation.](image)

The figure shows the block diagram for compensation of voltage sag and swells through injection transformer. The basic function of injection transformer is to increase or boost the voltage supplied by the filtered inverter unit to maintain desired level at load side the distribution network. The transformer winding ratio is predetermined according to the supply voltage required in the secondary side of the transformer (generally this is kept equal to the supply voltage to allow the DER to compensate for full voltage sag).

A higher transformer winding ratio will increase the primary side adversely affect the performance of the power electronic devices connected in the VSI [10]. The rating of the injection transformer is an important factor when deciding the DER performance, since it limits the maximum compensation ability of the DER.

### IV. CIRCUIT REPRESENTATION IN MATLAB SOFTWARE

The figure 4 shows the simulation diagram for sag and swell generation without DER using MATLAB/SIMULINK software.

![Fig.4. Model without VC-DER unit for sag/swell generation.](image)

In this model system operates at the frequency of 50 Hz and voltage of 11KV is given through three phase system. In this system, the various types of scopes can represents current and voltage values, and it will be gained by running these scopes. In this system L-G fault is to be considered for the duration of 0.1-0.2s. At the time of fault duration voltage sag is created and current swells. This drawback of the system can be overcome by using with VC-DER unit.
CONCLUSION

In this paper the VC-DER has been modeled and simulated in MATLAB software. The simulation shows that the DER performance is satisfactory in mitigating sags/swells. Simulation results also show that the DER compensates the sags/swells quickly and provides excellent voltage regulation. The DER handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value. The main advantage of this DER is low cost and its control is simple. It can mitigate long duration sags/swells efficiently.

REFERENCES


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