Green Power Zone

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Abstract

This paper presents the concept, prospect and operation of Green Power Zone (GPZ). The GPZ is defined as part of power grid which provides electrical energy with varying quality depends on customer requirement. Different power quality levels in the premium zone can rang from better than normal utility supply to a supply close to an ideal situation. Electrical energy to the zone is supplied through two feeders from two independent substations. The GPZ center is fully equipped with custom power devices, namely dynamic voltage restorer (DVR) and distribution static compensator (DSTATCOM) or even unified power quality conditioner (UPQC). The GPZ can also contain a distributed generator (DG) to take care the power interruption situations from the utility. The incoming feeders to the zone can be designed with improved grounding, insulation, arresters and reclosing. The simulation results are shown the performance of GPZ by using digital computer simulation program.

Key words: Green Power Zone, Custom Power Devices.

1. Introduction

With advancement in power electronic technology, it is now possible to supply very high-quality power to customers. Power electronic converter-based devices like the dynamic voltage restorer (DVR) [1], the distribution static compensator (DSTATCOM) [2], and unified power quality conditioner (UPQC) [3] can make either load side or source side or both sides free of harmonics and unbalance. A DVR can compensate for sag/swell and distortion in the supply side voltage such that load voltage remains balanced sinusoid. A DSTATCOM can compensate for distribution and unbalance in the load such that a balanced sinusoidal current flows through feeder. A UPQC can perform functions of both DVR and DSTATCOM.

The concept of Green Power Zone (GPZ) is defined as part of power grid which provides electrical energy with varying quality depends on customer requirement. Different power quality levels in the zone can rang from better than normal utility supply to a supply close to an ideal situation. Electrical energy to the GPZ is supplied through two feeders from two independent substations. Both these feeders are joined together via a solid state transfer switch (SSTS) [4]. This can make a subcycle transfer from the preferred to the alternative feeder such that the duration of any voltage sag can be reduced to 4-8 ms. The GPZ control center is fully equipped with custom power devices and GPZ can also contain a distributed generator (DG) [5] to take care the power interruption situations from the utility. The incoming feeders to the zone can be designed with improved grounding, insulation, arresters and reclosing. The SSTSs ensure that the feeder with higher voltage is selected in less than half a cycle in case of voltage sag. Using similar switching principle, these SSTSs can also be used to protect the loads of the zone from dynamic overvoltage as well. The DSTATCOM can provide reactive power support to the zone thereby maintaining the bus voltage. The DVR when operated in the voltage control mode can control the bus voltage.

So, the rest of this paper is organized as follows: Section 2 presents power quality and custom power devices to give the definition of these words. The power distribution system is discussed in section 3. A topology of a Green Power Zone is discussed in Section 4 which a DVR, DSTATCOM and DG are connected to regulate the voltage inside the park. Section 5 shows the simulation results by using MATLAB programme. Finally, the conclusion is given in Section 6.

2. Power Quality and Custom Power Devices

A. Power Quality

The term power quality is a rather general concept. Broadly, it may be defined as a provision of voltages and system design so that the user of electric power can utilize electric energy from the distribution system successfully, without interference or interruption.

This issue of electric power quality is gaining importance because of several reasons. The nature of electricity as a product is special, as discussed in IEEE 519, IEEE 1159 [6], EN 50160. Similar to the conventional products its characteristics affect its usefulness to the customer. Different from the conventional products the application if it is one of the main factors that has an influence on its characteristic. The current that the customer’s appliance draws from the supply network flows through the impedance of the supply system and causes a voltage drop, which affects the voltage that is delivered to the customer. Hence, both the voltage quality and the current quality are important. It is rather natural to split up the responsibilities so that the power distribution supplier is responsible for the voltage quality and the customer is accountable for the quality of current that he or she is taking from the utility.

Power quality problems are associated to an extensive number of electromagnetic phenomena in power systems with a broad range of time. For instance, it includes impulsive transients as well as frequency deviations. A comprehensive description of the categories and characteristics of power systems electromagnetic phenomena related to variations in the voltage magnitude is available in [7]. Fig. 1 shows the voltage sag and swell caused by remote fault that phase A and B are over 1.1 p.u. and phase C is under 0.9 p.u.

B. Custom Power Devices

Concerns on power quality problem have come into attention to many utilities and researchers for a decade. Many literatures devoted to obtain the methodology to find the way to prevent and relieve the power quality problem. The custom power had been proposed which concept of custom power and power electronic control in distribution areas by using the forced-commutation switches. It introduced the custom power solutions of power reliability rely on such novel components and systems as solid state circuit breaker (SSCB) and DSTATCOM, DVR and UPQC. Presently new systems for medium voltage grids with a compensation power of several MW are developed. Fig. 2 shows the basic concept of custom power devices. For a successful compensation, the custom power devices must be able to detect voltage disturbances and control the converter to prevent against sags, swells, flicker, harmonic, etc.

Fig. 2(a) shows the series-connected device namely DVR to inject the voltage into the grid. The amplitude, phase and frequency are controlled. The shunt-connected device, DSTATCOM, is the harmonic and unbalanced voltages control as shown in Fig. 2(b). The compound-connected, both series and shunt, is connected into the grid. The load voltage and supply current are controlled closed to the idea situation as shown in Fig. 2(c).

3. Distribution Systems

The term electric power quality broadly refers to maintaining a near sinusoidal power distribution bus voltage magnitude and frequency. In addition, the energy supplied to a customers must be uninterrupted from the reliability point of view. It is to be noted that even though power quality is mainly a distribution system problem. This is because the modern transmission systems have a low resistance to reactance ratio, resulting in low system damping. Usually, a well-designed generating station is not a source of trouble for supplying reserve which ensures that the generating capability remains more than the load may demand. In some cases, a temporary shortfall in generation is overcome by reducing the peak of the generated voltage to reduce power consumption.

In this study the power distribution system uses the simple system with 22 kV voltage level. System should operate at normal frequency and voltage to maintain the quality of supply. A simple model for calculating the resulting voltage, i.e. the voltage magnitude during disturbance, is based on radial systems. In case of sensitive load, the proposed compensation devices have to take care on that region. Power distribution systems need to be highly service-oriented and caring for customer values. Fig. 3 shows the simplified diagram of the simple model when we study as the simple voltage divider in this paper. In the normal and abnormal operation the resulting voltage and phase angle will be:

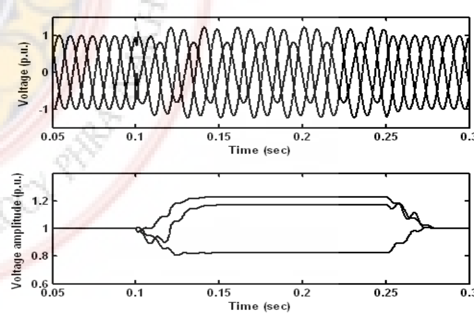
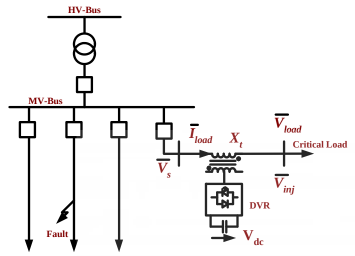
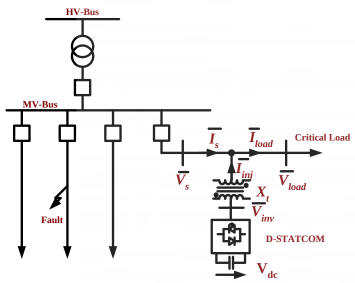


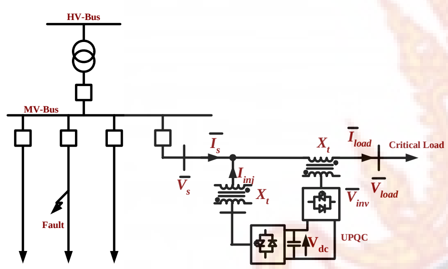
Fig. 1 Voltage sag/swell due to a fault (a) waveforms (b) amplitude.



(a) Dynamic Voltage Restorer



(b) Distribution Static Compensator



(c) Unified Power Quality Conditioner

Fig. 2 Simplified diagram of custom power devices connected between supply network and a critical plant.

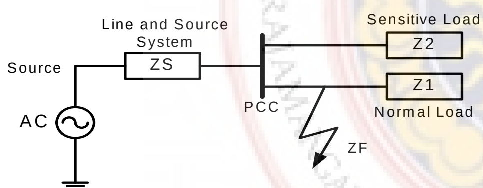


Fig. 3 Simplified diagram of the simple model.

$$Z_L = Z_1 // Z_2 \quad (1)$$

Point of common coupling (PCC) voltage defines with:

$$\overline{V}_{PCC} = \frac{\overline{Z}_N}{\overline{Z}_S + \overline{Z}_N} \quad (2)$$

$$V_{PCC} = \left| \frac{Z_N}{Z_S + Z_N} \right| \quad (3)$$

$$\phi_{PCC} = \tan^{-1}\left(\frac{X_N}{R_N}\right) - \tan^{-1}\left(\frac{X_N + X_S}{R_N + R_S}\right) \quad (4)$$

when

$Z_1 = R_1 + jX_1$ (Load 1 impedance)

$Z_2 = R_2 + jX_2$ (Load 2 impedance)

$\overline{V}_{PCC}$: Voltage phasor at the PCC point

V_{PCC} : Voltage magnitude at the PCC point

ϕ_{PCC} : Phase angle of voltage at the PCC point

4. Green Power Zone

A. Concept

In a GPZ all customers of the zone should benefit from high quality power supply. Even the basic form of this supply is superior to the normal power supply from a utility. Electrical power to the zone is supplied through two feeders from two independent substations as shown in Fig. 4. Both these feeders are joined together via a SSTS. This can make a subcycle transfer from the preferred to the alternative feeder such that the duration of any voltage sag can be reduced to 4-8 ms.

Fig 4, a topology of GPZ is discussed in which a DSTATCOM is connected to regulate the current and voltage flicker inside the zone, a DVR is connected to regulate the voltage sag and swell and DG is connected to support the power interruption.

B. Prospect

As we define the GPZ is the zone that have the high quality power supply, the customer can choose the high quality of power by themselves. The custom power devices refer to the production of power quality compensation are connected at or near the place of consumption. This application differs from the infrastructure for supplying electricity that utilities have built over the past five decades. Under that infrastructure, utilities typically have built power plants away from centers of consumption, on the basis of such factors as fuel transportation costs and environmental regulations, and then moved that electricity long distances over high-voltage transmission lines to local distribution systems. The GPZ can help to prevent the energy cost and to produce the high quality of power. The customers can select the coming power. The different level of coming is provided by GPZ organizer or local utility. The highest level of coming power must get the highest quality of power without any problems, while the highest level must spend highest cost as well. So, the customer have to consider the type of loads inside the zone before buying the coming power.

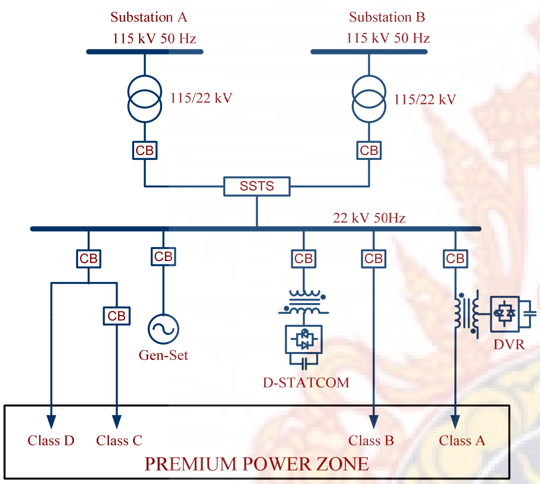


Fig.4 Green Power Zone

C. Operation

The incoming feeders to the zone can be designed with improved grounding, insulation, arresters and reclosing. The SSTSs ensure that the feeder with higher voltage is selected in less than half a cycle in case of voltage sag. Using similar switching principle, these SSTSs can also be used to protect the loads of the zone from dynamic over voltage as well. The DSTATCOM, when operated in the voltage control mode, can provide reactive power support to the zone thereby maintaining the bus voltage. A DVR can compensate for sag/swell and distortion in the supply side voltage such that load voltage remains balanced sinusoid. DG can sadden connect to the grid when the power interruption situations from the utility. Under the configuration shown in Fig. 4, there are four different grades of power that can supplied to the zone's customers. These are as follows;

Class A: This is the basic quality power. Since the transfer switches protect the incoming feeders, the quality of the power is usually superior to normal utility supply.

Class AA: This includes all the feature of Class A. In addition, this class has the benefit of low harmonics power due to DSTACOM

Class AAA: This includes all the feature of Class AA. In addition, it receives the benefit of a distribution generator. The DG can be brought into service in about 10-20 seconds in case of a serious problem such as power failure in both feeders.

Class AAAA: This includes all feature of Class AAA. In addition, it has the benefit of receiving distortion or sag free voltage due to the DVR.

Under normal operating conditions, the DSTATCOM, DVR and Gen-set stay off and are disconnected from the bus and customers of the Class AA, Class AAA and Class AAAA. The difference in power quality becomes apparent when power to both feeders is lost simultaneously due to a fault in the power system. When both feeders are lost, the loads belonging to customers of both these classes are removed through circuit breakers. This reason, the Gen-set is switched on and then the power to Class AAA and Class AAAA customers by closing of the circuit breakers connected to the Class AAA and Class AAAA customers. This means that customers of Class AAA do not lose power for more that 10-20 seconds under any situation. The customers of Class A and Class AA however do not receive power until one of the feeders is back in service. The Class AAAA customers are not affected by the loss of the both feeders as their voltage is maintained by DVR till the Gen-set comes into service. Since the Gen-set gas to be started instantaneously, brought to speed and synchronized within less than 20 seconds, it must be driven by s diesel or a gas turbine.

It is to be noted that the DVR must provide voltage support for the Class AAAA supply in case of the both feeder failures till DG is synchronized with the bus. This implies that it may have to provide this support for about 20 seconds. It is therefore important to ascertain whether a DVR that is supplied by ac storage capacitors is capable of holding the voltage for such a long time or not. Alternatively, the DSTATCOM and the DVR in the premium power control center can be replaced by a single UPQC that will be able to perform both the functions of harmonic neutralization and voltage balancing simultaneously.

Through the GPZ it is possible to supply power to different types of sensitive loads ranging from shopping malls and hospitals to semiconductor manufacturing. For example, sudden voltage sag can cause the loss of a few hours of production. With modern and life support equipment, a hospital on the other hand, requires both AAA and AAAA class supplies. The class AAAA connection can be supplied to the operating theaters and life support systems, while the Class AAA connection can be given to the rest of the building along with pathology and other testing facilities. Most shops in a shopping center or offices in an office building require Class A and AA power. The class of the quality of the power a customer in the zone receives depends on the nature of its load and the price he is ready to pay.

5. Simulation Results

In this section, the behavior of the GPZ is investigated in MATLAB. The system model and the methodology used for simulation are discussed in Appendix B. For all cases given in this paper the electrical system parameters are given in Appendix A in per unit. In this a phase angle, a difference of 15° between the two source voltage is assumed. For maintaining the continuity of supply of the zone, the preferred feeder (Substation A) and alternative feeder (Substation B) are connected to two separate substations. To represent source voltage phase angles and feeder impedances are chosen. The base quantities are the distribution system voltage and VA rating of the GPZ, e.g., 22 KV and 20 MVA. The time has not been normalized. Therefore, the base for energy is the same as that for power, i.e., base VA. The dc side voltage can be normalized to the base voltage taking into account the turns ratio of the coupling transformer. The base dc capacitor value is the reciprocal of the base impedance.

Fig. 5 shows the operation of SSTS when the transfer switches protect the incoming feeders, the quality of the power is usually superior to normal utility supply as Class A. The benefit of low harmonics power due to DSTATCOM is presented in Fig. 6 as Class AA. Class AAA, Fig. 7, shows the DG connection to reserve the power interruption. Finally, the DVR is connected to the grid as shown in Fig. 8, namely Class AAAA, it has the benefit of receiving distortion or sag free voltage.

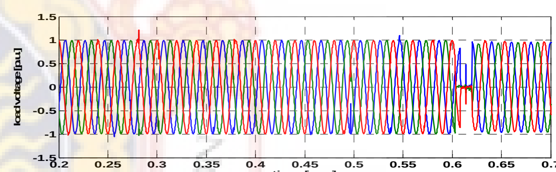


Fig.5 System response during Class A operation.

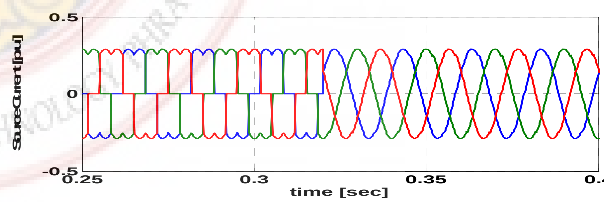


Fig.6 System response during Class AA operation.

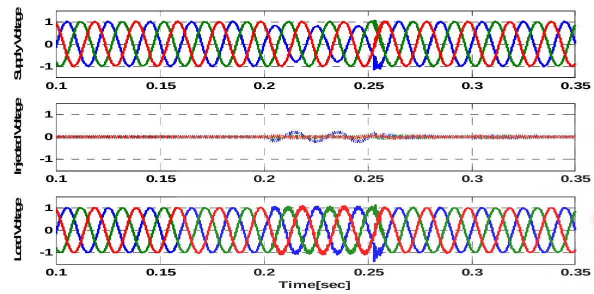


Fig.7 System response during Class AAA operation.

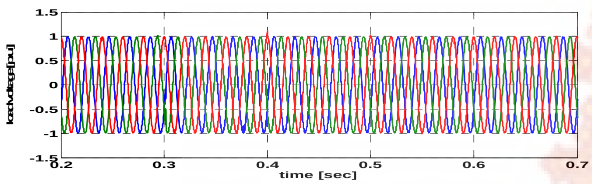


Fig.8 System response during Class AAAA operation.

6. Conclusion

This paper illustrates the concept, prospect and operation of Green Power Zone in which all the loads get a regulated bus voltage. The bus voltage regulation is performed by DSTACOM. DVR and DG. It has been shown that by a proper choice of custom power devices, they are possible to hold the terminal voltage when both feeders are lost due to any catastrophic failure. The GPZ center is fully equipped with custom power devices, DSTATCOM eliminates harmonics and/or unbalanced, while DVR eliminates any voltage sag or distortion. The GPZ can also contain a DG to take care the power interruption situations from the utility.

Appendix A: System Parameters given in per unit

System Quantities	Values
System frequency	50 Hz
Source Vs1	Peak Amplitude, phase angle 0°
Source Vs2	Peak Amplitude, phase angle 30°
Preferred feeder	Impedance: 0.025 + 0.2i
Alternate feeder	Impedance: 0.05+0.3i
Load class A	Impedance: 1+2i
Load class AA	A controlled rectifier with delay angle 30° drawing a peak current of 0.25.
Load class AAA	Impedance: 2+2.5i
Load class AAAA	Impedance: 0.2+1.5i, 2.55+1.25i and 1.0+2.3i in phases a, b and c respectively
DSTATCOM	Transformer leakage reactance 0.2 Rf+ jωLf = 0+2i
DVR	Transformer leakage reactance 0.2 Rf+ jωLf = 0+2i
Distributed Generator	10 MW

7. References

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