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Amelioration of Power Quality in Isolated Power Systems

I.Kumaraswamy, W.V.Jahnavi, P.Ramesh

Department of Electrical& Electronics Engineering, Sree Vidyanikethan Engineering College,
Andhra Pradesh, India

Abstract- In Isolated power systems the power quality problem is compounded as the drive converter loads are likely to fluctuate in conjunction with mining or exploration areas. The use of compensators in improving power quality of isolated power systems is considered. The roles of the compensators are to mitigate the effects of momentary voltage sags/swells, and to control the level of harmonic distortions in the networks. A control strategy for both series compensator and shunt compensator is developed to regulate power flow. However series compensator reduces harmonics to an acceptable level when compared to shunt compensator. This is achieved through phase adjustment of load terminal voltage. It leads through an increase in ride through capability of loads to the voltage sags/swells. Validity of the technique is illustrated through simulation. Hence series compensator with LC Filter is used in reducing the harmonic distortions in isolated power systems.

Index Terms- Power Quality, Harmonic power flow, isolated power system, phase shift, series compensation, Shunt compensation

I. Introduction

Isolated power systems are commonly found in rural and remote areas of the world. These systems represent the alternative to grid connection, where interconnection to a large grid is not viable due to high cost and/or geographical obstacles. Furthermore, power systems such as those onboard of ships, in oil exploration areas and remote mining districts are characterized by limited generating capacity, supplying loads which can consist of significant amount of motor drives and power converters.

The power systems are often considered weak in that they possess relatively low short-circuit ratio, in comparison to a grid. Network voltage control becomes a challenging task as a result. The power-quality (PQ) problem is compounded as the drive-converter loads are likely to fluctuate in conjunction with the mining or exploration activities Fig. 1 shows a typical isolated power system supplying a converter load. The RL load may be used to represent an aggregate of dc motor drives, supplied via the converter. The converter is often a controlled six-pulse rectifier through which the motor torque is regulated by adjusting the firing angle of the rectifier. The motor-drive load is nonlinear and would involve commutation process within the converter. The consequence would be distortions in the voltage/current waveforms in the supply system, the extents of which are likely to fluctuate as the load changes [1], [2].In addition to the drive load, one can also expect the presence of lower power capacity-sensitive loads, such as computers or electronic controllers in the power system. The equipment is needed to ensure the proper functioning of the exploration mining activities. The sensitive loads would be connected in parallel with the nonlinear drive. Often such sensitive loads also contain input rectifiers that are capacitive in nature. The combined sensitive loads may be represented by the parallel RC circuit shown in Fig. 1. While the total capacity of the sensitive loads could be much smaller than that of the main drives, the distorted supply voltage is harmful to the sensitive loads. Excessive voltage distortions could cause the sensitive loads to mal-operate. The loads are also sensitive to short-duration disturbances in the form of voltage sags or swells. The disturbances can be due to faults or most likely, the fluctuating load cycles of the main drives. In the latter case, voltage flickers can occur and they can be of major concern. Thus one important consideration in the design and operation of the power system would be to ensure that the quality of supply to the sensitive loads comply with that prescribed under industry standards, such as the ITI curve [3].A traditional method to achieve improved PQis to use passive filters connected at the sensitive load terminals [4]. However, this practice has some shortcomings: the effectiveness of the scheme could deteriorate as the source impedance or load condition changes; it can lead to resonance between the filter and the source impedance. For these reasons, active filters such as that described in [5] may be used. Essentially an active filter, connected at the sensitive load terminal, injects harmonic currents of the same magnitude but of opposite polarity to cancel the harmonics present there. However, as noted earlier, harmonic distortions are only part of the problem faced in such a network: the variations in the drive load would result in voltage sag/swell or flickers appearing in the upstream voltage. Thus, the challenge is to regulate the sensitive load terminal voltage so that its magnitude remains constant and any harmonic distortion is reduced to an acceptable level. In a recent study, [6] proposes a series compensation method to mitigate the harmonics problem for the power system shown in Fig. 1. However, compensation for voltage sag/swell or flicker has not been considered. Series voltage compensation methods have been discussed in [7], [8] for the mitigation of short-duration voltages/swells but the presence of harmonic voltages/current in the networks has been ignored. This paper intends to fill this gap. Specifically, the investigation is to develop a method to control the fundamental component of . The control is achieved by regulating power flow via phase angle adjustment. Unlike the previous methods of [6]–[8], the investigation also shows that the voltage-sag ride through capability of the sensitive load can be improved through importing harmonic power from the external system into the SC.

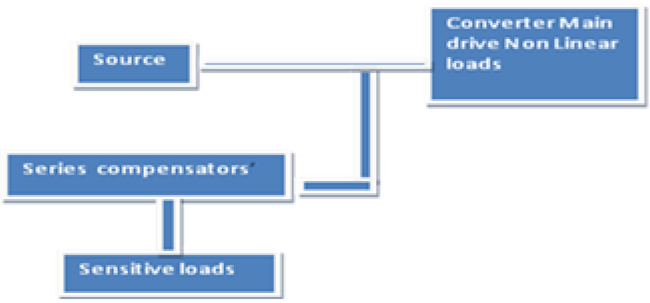


Figure 1: Typical isolated power system installed with a Series compensators.

II. Power Quality

"POWER QUALITY" is defined as "the concept of powering and grounding electronic equipment in a manner that is suitable to the operation of the equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment.

Power quality has become a strategic issue for the following reasons:

1. The economic necessity for businesses to increase their competitiveness.

2. The widespread use of equipment which is sensitive to voltage disturbances and /or generates disturbances itself.

3. The deregulation of the electricity market.In this context, it is essential for the utility and the customers to prevent and detect power quality problems and to have solutions available to fix them.

4. The power quality correction and harmonic filtering system give solution to solve the problems of harmonic disturbances and voltage fluctuations.

Power Quality Glossary:

Although specialists use complex equations for precise descriptions and analysis, the following definitions are adequate for most discussions
with your local utility account managers, distribution engineers, and PQ consultants and vendors.

Harmonic distortion: Continuous or sporadic distortions of the 60-hertz (Hz) voltage sine waveform, usually caused by microprocessor based loads in the building such as computer power supplies, lighting ballasts, and electronic adjustable speed drives. Harmonics can also be transmitted from an energy user down the block. These can cause telecommunications or computer interference; overheating in motors, transformers, or neutral conductors; decreased motor performance; deterioration of power factor–correction capacitors; or erratic operation of breakers, fuses, and relays.

Interruption, momentary*:* A very short loss of utility power that lasts up to 2 seconds, usually caused by the utility switching operations to isolate a nearby electrical problem.

Interruption, temporary*:* A loss of utility power lasting from 2 seconds to 2 minutes, caused by a nearby short circuit due to something like animals, wet insulators, or accidents. Corrected by automated utility switching

Long-term outage*:* A loss of utility power lasting more than 2 minutes due to major local, area, or regional electrical events.

Noise*:* Sporadic voltage changes consisting of frequencies higher than the normal 60-Hz power frequency due to any number of causes, including arc welders, loose wiring, and nearby radio and TV transmitters.

Sag*:* A short-term decrease in voltage lasting anywhere from milliseconds up to a few seconds. Sags starve a machine of the electricity it needs to function, causing computer crashes or equipment lock-ups. Usually caused by equipment start-up—such as elevators, heating and air-conditioning equipment, compressors, and copy machines — or nearby short circuits on the utility system.

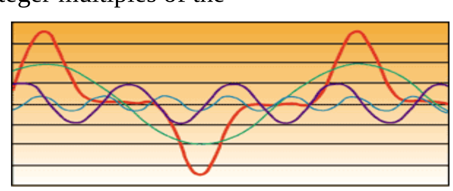
Spike*:* A very brief (nanoseconds to milliseconds) change in voltage ranging from tens to thousands of volts. Can be produced by utility and customer equipment operations, nearby lightning strikes, falling tree limbs on power lines, and even static discharges.

Surge: A short-term increase in voltage, lasting up to a few seconds. They are due either to customer equipment operation, such as air conditioners or motors switching on and off, or to utility activities, such as capacitor switching.

Transient*:* A sudden momentary change in voltage. Also called a spike

III. Harmonics

Harmonics are currents or voltages with frequencies that are integer multiples of the



Fundamental power frequency: The fundamental frequency itself is called as the first Harmonic. The second Harmonic as frequency twice that of the fundamental, the third Harmonic has frequency thrice that of the fundamental and so on. For example – if the fundamental frequency is 50Hz then the second Harmonic is 100 Hz, the third Harmonic is 150Hz etc.

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1. Generation of Harmonics:-

Harmonics are created by non-linear loads that draw currents abrupt pulses rather than in a smooth sinusoidal manner. These pulses cause distorted current wave shapes, which in turn cause harmonic currents to flow, back into other parts of the power system.

2. Consumers Generating Harmonics:

Harmonics are not generated by power generators but are produced by Non-linear loads as under:
Loads that make use of semi conductor devices
Like transistor, thyristor i.e., static rectifiers. (AC/DC conversion using SCRs), static frequency converters, static inverters like:
Static Power converters (AC – DC conversion using SCRs)
Static rectifiers
Static frequency converter
Static uninterrupted power supplies
Static induction regulators

Variable impedance loads, using electric arcs, are furnaces, welding units, Fluorescent tubes, discharge lamps, light control, brightness etc.,
Loads using strong magnetizing currents, saturated Transformers, inductance, furnaces, reactors etc.Office automation equipment like computers, UPS, printers and fax machine etc.

IV. VOLTAGE SAG

Voltage sag is a sudden reduction (between 10% and 90%) of the voltage magnitude at a point in the electric System and lasting from 0.5 cycles to few seconds. Either switching operations or any type of faults as well as fault clearing process can cause a voltage dip. Switching like those associated with a temporary disconnection of the supply or flow of heavy currents associated with the starting of large motor loads is the most common. These events maybe originated at the utility side or at the customer site.

V. POWER QUALITY CHARACTERIZATION

Even the most advanced transmission and distribution systems are not able to provide electrical energy with the desired level of reliability for the proper functioning of the loads in modern society. Modern T&D (transmission and distribution) systems are projected for 99,9 to 99,99% availability. This value is highly dependent of redundancy level of the network, which is different according to the geographical location and the voltage level (availability is higher at the HV network). In some remote sites, availability of T&D systems may be as low as 99%. Even with a 99,99% level there is an equivalent interruption time of 52 minutes per year. The most demanding processes in the modern digital economy need electrical energy with 99.9999999% availability (9-nines reliability) to function properly. Between 1992 and 1997, EPRI carried out a study in the US to characterize the average duration of disturbances. The result for a typical site, during the 6-year period is presented below.

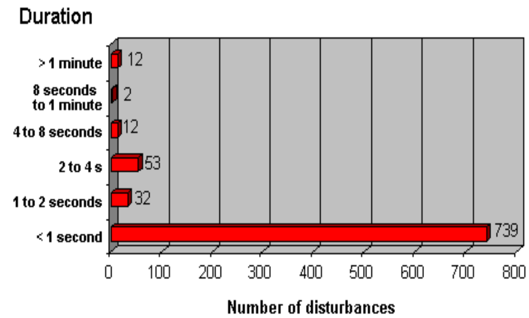


Figure 3: – Typical distribution of PQ disturbances by its duration

VI. SIMULATION RESULTS

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

1. REDUCING HARMONICS USING SHUNT COMPENSATOR:

In the isolated power systems the harmonics are reduced to a small extent due to shunt compensator as shown in fig 4. The 3-phase terminal voltage waveforms due to the shunt compensator at the sensitive load terminal are not completely perfect sinusoidal, and are present with some amount of harmonic disturbances. The voltage waveforms at the sensitive load terminal are shown in below figure 5

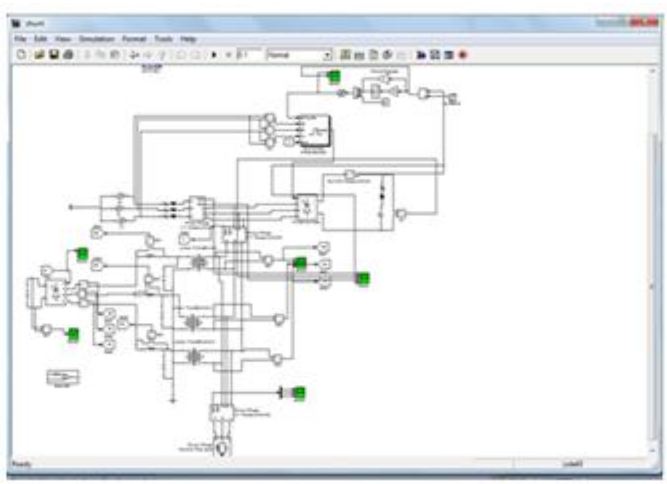


Fig: 4Shunt Compensators

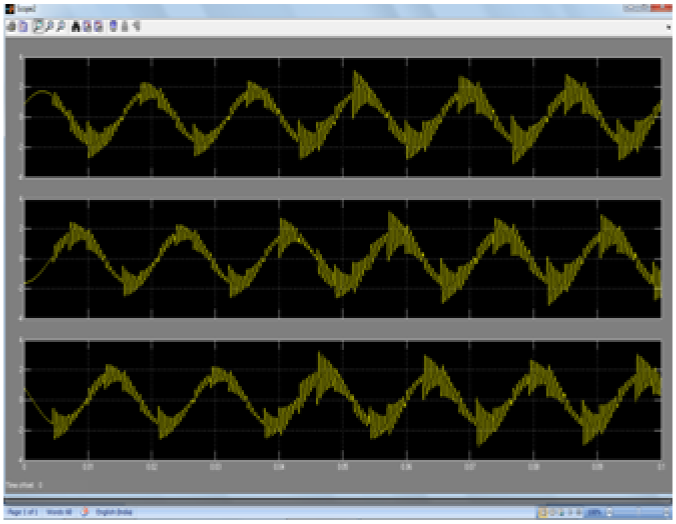


Fig: 5 the voltage waveforms at the sensitive load terminal.

2. REDUCING HARMONICS USING SERIES COMPENSATOR:

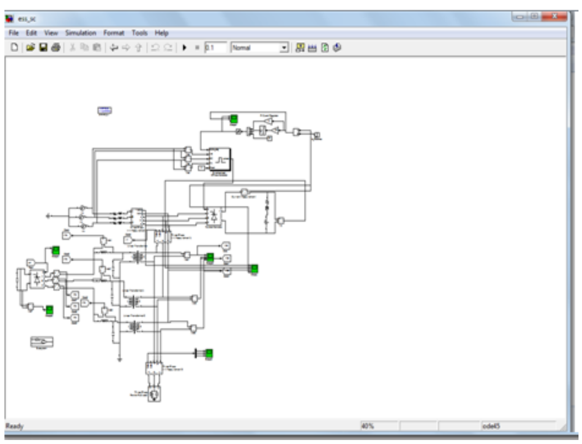


Fig 6.Series Compensator

The use of series compensators as shown in fig 6 reduces harmonics to an acceptable level when compared to a shunt compensator. The voltage waveforms at the sensitive load terminal are shown in below fig7

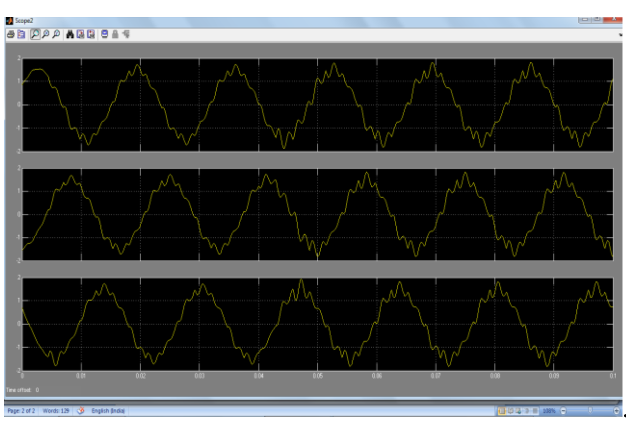


Figure 7: The voltage waveforms at the sensitive load terminal.

From the above wave forms we can analyze that the series compensator reduces the harmonics to a greater extent when compared to shunt compensator. Hence the series compensator is used in the isolated power systems for protection of sensitive loads.

3. USAGE OF LC FILTERS:

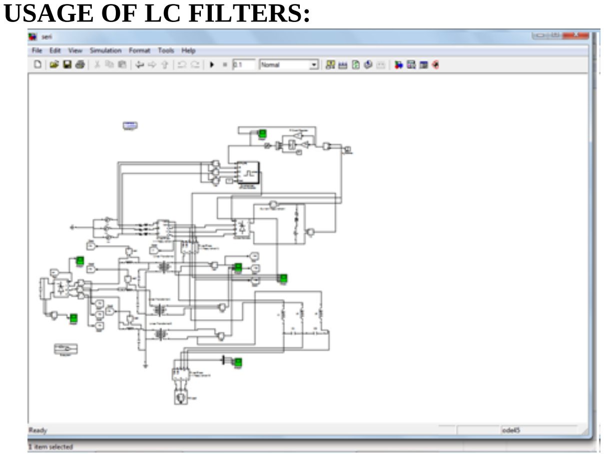
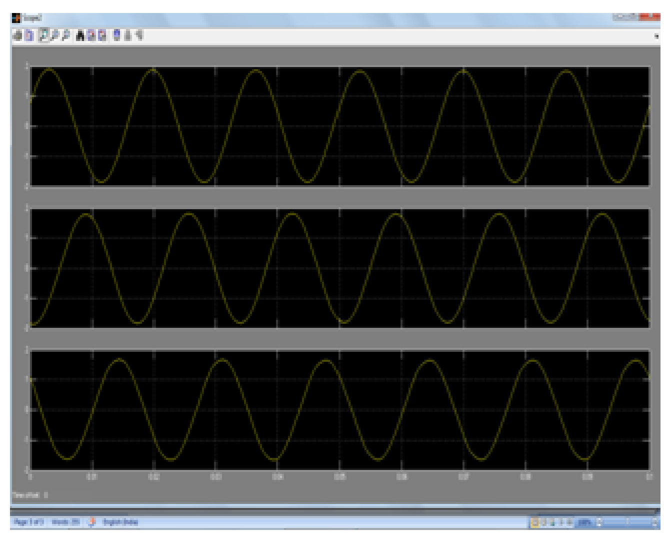


Fig 8.LC filters

The series compensator is used in reducing the harmonics in the isolated power systems for the protection of sensitive loads, but the use of series compensator cannot eliminate the harmonics completely in load terminal voltage.



Hence LC filters as shown in fig 8. is used to eliminate the harmonics completely in addition with series compensator. The voltage waveforms at the sensitive load terminal are shown in below figure 9.

Hence from the above waveforms we can conclude that the use of LC filter in addition with series compensator completely eliminates the harmonics in the load voltage at the sensitive load terminals in isolated power systems.

VII. CONCLUSION

In the isolated power systems the harmonics are reduced to a small extent due to shunt compensator. The 3-phase terminal voltage waveforms due to the shunt compensator at the sensitive load terminal are not completely perfect sinusoidal, and are present with some amount of harmonic disturbances.

The use of series compensators reduces harmonics to an acceptable level when compared to a shunt compensator.

The series compensator is used in reducing the harmonics in the isolated power systems for the protection of sensitive loads, but the use of series compensator cannot eliminate the harmonics completely in load terminal voltage. Hence LC filter is used to eliminate the harmonics completely in addition with series compensator.

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AUTHORS

I.Kumar Swamy obtained his B.Tech in Electrical & Electronics Engineering from JNTU Hyderabad University at Narayana Engineering College, Nellore M .Tech-EPS at Sri Vidyanikethan Engineering. College, Tirupati. Areas of interest are power system analysis, application of FACTS devices using in Transmission systems, Power System Stability, Voltage Stability
Kumarswamy04@gmail.com

Second Author – W.V.Jahnavi, Assistant Professor, Department Of Electrical& Electronics Engineering, Sree Vidyanikethan Engineering College, Andhra Pradesh, India
wvjahnavi@gmail.com

Third Author – P.Ramesh, Assistant Professor, Department Of Electrical& Electronics Engineering, Sree Vidyanikethan Engineering College, Andhra Pradesh, India
pramesheee@yahoo.co.in