ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

Power Quality Improvement in Underground Mining

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ABSTRACT:The application of electricity to the mining industry is a distinctive area of both mining and electrical engineering. Power Quality is defined as "any occurrence manifested in current, voltage, or frequency deviations that results in damage, upset or failure of end-use equipment's. It is common experience that electric power of poor quality has detrimental effects on health of different equipment and systems. The focus on Power Quality problems has recently become one of the important issues in power systems due to fast industrialization and extensive use of nonlinear loads. The Power Quality management is the key issue in electrical power system and industries are facing these issues around the world. As the mining complexes are often remotely located, power is weak and unpredictable. Loads such as continuous miners mine hoists, mining shovels, crushers, etc. are in demand and also sensitive to voltage dips and fluctuations. Voltage dips or sags often causes equipment to trip, which in turn results in lengthy delays with resultant production and revenue losses. In this paper Proportional Controller (PI) controller is implemented using MATLAB / SIMULINK

KEYWORDS:Power Quality, Mine, Loads, Custom Power Devices.

I. INTRODUCTION

The Feeding safe and reliable power to mining complexes can be a challenging task. As per the Indian Electricity rules 1956 transformers, not allowed inside a mine [1]. The difficult environment, the dynamic power loads, the cyclic and mobile operation and stringent safety requirements that characterize mining, all places unique demands on the mine power system. No other industry makes such extensive use of portable extensible equipment or has such complex grounding problems. Mine power systems can range from relatively simple installations for small surface mines to complex underground systems where the harsh environment of dust, humidity, and cramped spaces stretches the ingenuity and creativity of the engineer to provide reliable service. But today's mine power system is both complex and subject to numerous legal constraints, and it is no longer possible to treat it with the indifference of the past. The distance from the secondary power transformers to the working point inside a mine, are fairly long.This results in high voltage drops in the cables and poor voltages in the operating equipments. With all restrictions in high voltage capacitors, a substantial reactive power is generated through capacitor banks and supplied near the main transformer only [2]. However, this does not help in improving the voltage at the equipment terminals. The voltage at the equipment terminals determines the starting and running torques. Mining operation performance is strategically linked to the efficiency of the electrical motors that run countless operations across a plant. Loads such as continuous miners mine hoists, mining shovels, crushers, etc. are in demand and also sensitive to voltage dips and fluctuations**.** Mining complexes are often forced to operate in environments characterized by one or several of the following factors:

- Remote areas where power supplies are weak or inadequate
- Rough, inaccessible terrain, more or less unsuited for OH (Overhead) line construction

A traditional way to deal with shortcomings in power transmission as well as with poor or insufficient power quality is reinforcing the grid by building new lines, upgrading voltages to higher levels, or building local power plants to supply parts or the total of the load. Such measures are expensive and time-consuming, if, they are permitted. A cost effective way to introduce custom power devices, thereby utilizing existing facilities more efficiently. The proper use of this technology will benefit mining industry with the following benefits;

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- Continual energy efficiency
- Extended equipment life
- Reduced costs and
- Reduced voltage fluctuations

II. REVIEW OF LITERATURE

The quality of power delivered to the end user is very important as the performance of the consumer's equipment is heavily dependent on it. But the power quality is affected by various factors like voltage and frequency variations, presence of harmonics, faults in the power network etc. Among them the voltage variations (sag) is one of the most frequently occurring problem. There are many methods to mitigate the voltage sag and among them the best way is to connect a CUSTOM POWER device at the point of interest. The well-known devices like DSTATCOM, DVR, and UPQC are used for this purpose.

Gothelf Natan et al identified the hoisting system in the iron ore mine as fast changing load that affects Power Quality of the electrical system [3]. Grunbaum et al. explained that FACTS (Flexible AC Transmission Systems) devices improve power supply to mining industry [4].

III. POWER QUALITY

Power quality, like quality in other goods and services, is difficult to quantify. There is no single accepted definition of quality power. There are standards for voltage and other technical criteria that may be measured, but the ultimate measure of power quality is determined by the performance and productivity of end-user equipment. If the electric power is inadequate for those needs, then the "quality" is lacking.

Hence power quality is ultimately a consumer-driven issue, and the end user's point of reference the power quality is defined as "Any power problem manifested in voltage, current or frequency deviations that results in failure or misoperation of customer equipment "[5].

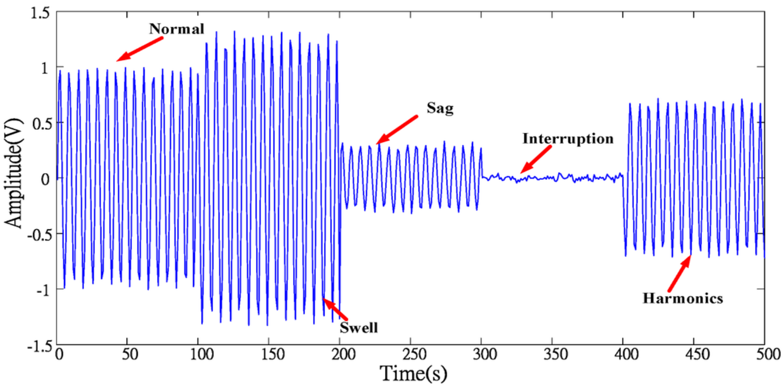

Figure 1. Power Quality problems

In the figure 1 it shows the graph of time vs various Power Quality problems. The commonly used terms those describe the parameters of electrical power that describe or measure power quality are sags, swells, interruptions, harmonics etc. are shown in figure 1.

IV. CUSTOM POWER DEVICES

The voltage sag is a major problem that the power system network is facing now-a days. This is a severe problem and affects the functioning of the equipment. Therefore, this problem should be mitigated in order to maintain the efficiency of the power network. The use of custom power devices solves this problem. The concept of custom power was introduced by N.G. Hingorani in 1995 as an extension of the FACTS concept to distribution systems. The major objective is to improve power quality (PQ) and enhance reliability of power supply. The concept of FACTS was also

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proposed by Hingorani in 1988. The term 'custom power' describes the value-added power that electric utilities will offer their customers. The value addition involves the application of high power electronic controllers (similar to FACTS) to distribution systems, at the supply end of industrial, commercial customers and industrial parks. The provision of custom power devices (CPD) is complementary to the individual end-use equipment at low voltages (such as UPS (Uninterruptible Power Supply) or standby generators) [5].

V. BASIC PRINCIPLE OF DSTATCOM

D-STATCOM is a shunt-connected CPD which can be used to regulate voltage variation resulting from the motor starting condition or in-rush current and to mitigate current harmonic distortions. A DSTATCOM is a controlled reactive source which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and /or absorbing reactive power. It is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, gives an instantaneous response, does not alter the system impedances, and can internally generate reactive (both capacitive and inductive reactive power). Figure 2. shows the basic structure of a DSTATCOM. If the output voltage of the VSC is equal to the AC terminal voltage; no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages. The control algorithms studied in this paper are applied with a view to study the performance of a DSTATCOM for compensation of voltage [6].

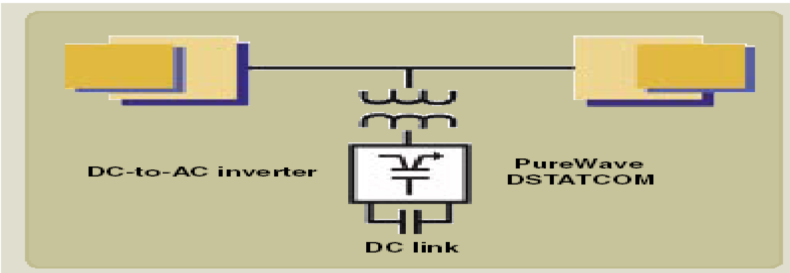

Figure 2. Basic block diagram of DSTATCOM

VI.UNDERGROUND MINE POWER SYSTEM

Underground mine power systems have different characteristics from those for surface mines. As shown in figure 3, underground mine power systems are somewhat more complicated than those for surface applications .Because of the nature of the mine and its service requirements, distribution must almost always be radial (Figure .3), the freedom in routing distribution enjoyed by surface mines is not available underground [2].

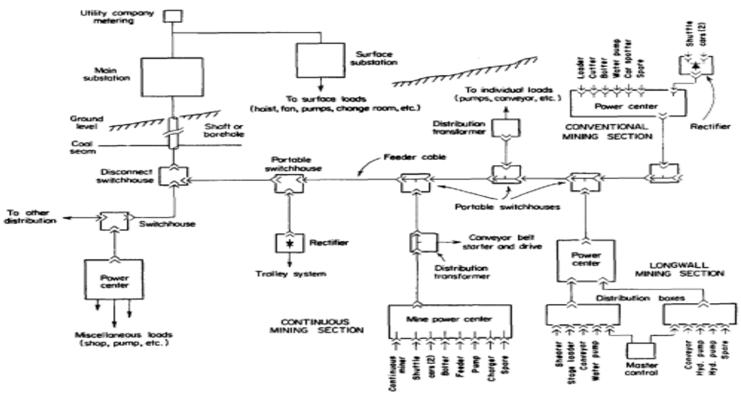

Figure 3. Radially distributed underground power system [2]

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A typical Longwall mining system as shown in Figure 4 consists of several electrically operated components, interfaced with the coal-haulage system for the time. The major components are the shearer unit, shearer controller, face conveyor unit, stage-loader unit, conveyor controller, hydraulic pump unit, pump controller, master controller and power centre. Figure 2 shows shearer cutting Longwall face at GDK 10A underground mine. The goal of the power engineer is to provide an efficient, reliable electrical system at maximum safety. All power equipment used in underground must be rugged, portable, self-contained, and specifically designed for installation and operation in limited spaces. In addition, all equipment and the cables connecting them must be protected against any failures that could cause electrical hazard to personnel. The designed system must meet certain minimum criteria. IEEE has defined these basic criteria for industrial electrical systems that must be applied to mines:

- Safety to personnel and property
- Reliability of operation
- Simplicity
- Maintainability
- Adequate interrupting ability
- Current-limiting capacity
- Selective-system operation
- Voltage regulation and
- Potential for expansion

Figure 4. Shearer cutting at Longwall face [7].

VII. CONTROL STRATEGY

The main objective of any compensation scheme is that it should have a fast response, flexible and easy to implement [7].The control algorithms of a DSTATCOM are mainly implemented in the following steps

- Measurements of system voltages and current and Signal conditioning.
- Calculation of compensating signals.
- Generation of firing angles of switching devices

7.1 PI Controller:

In this control algorithm the voltage regulation is achieved in a DSTATCOM by the measurement of the RMS voltage at the load point and no reactive power measurements are required. Figure. 5 shows the block diagram of the Implemented scheme.

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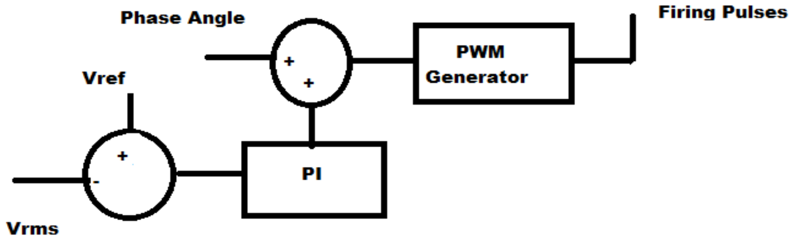


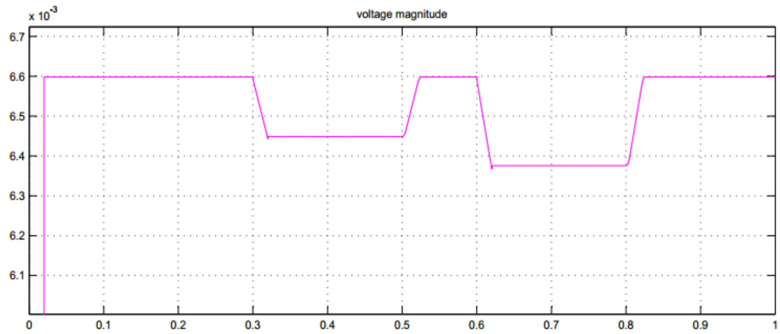
Figure 5. Block diagram of PI controller

VIII. RESULTS

Electrical data has been collected from GDK-10A underground mine and based on the data collected, power system model has been developed in MATLAB / SIMULINK. The simulations are performed for the cases: (i) without compensation and (ii) with compensation. The system performance is analyzed. These cases are summarized below:

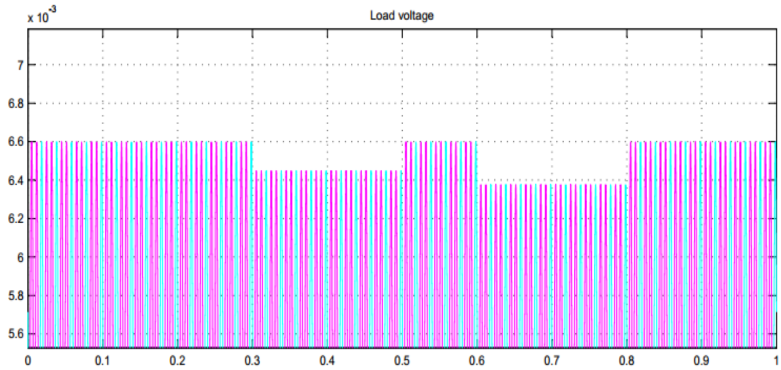
Case (1): Without compensation

Model has been simulated for one second and load 1 (375 KW) is switched on between 0.3 to 0.5 sec and load 2 (250KW) is switched on between 0.6 to 0.8 sec. After switching ON the load, the voltage was falling down and decreased to a certain level. Simulation results are shown in Figure 6 (a) & (b). The Total Harmonic Distortion (THD) without compensation observed is 28 % at 50 Hz fundamental frequency which is high.



6 (a) Load voltage Magnitude

In this figure 6 (a) it shows the graph of time vs voltage magnitude without compensation. We can observe from the figure at 0.3 sec to 0.5 sec and 0.6 sec to 0.8 sec there is a sag in the voltage.



6 (b) Load voltage

Fig. 6 (a) & (b). Simulation Result without PI controller

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ISSN (Online): 2278 – 8875

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In this figure 6 (b) it shows the graph of time vs load voltage without compensation. We can observe from the figure at 0.3 sec to 0.5 sec and 0.6 sec to 0.8 sec there is a large variations in voltage which is undesirable. There are harmonics present in the waveform.

Case (2): With compensation

After PI controller is added the results obtained from the simulation shows that the compensation offered by PI is much better than without compensation. The THD is reduced to 15.12 % and result is shown in Figure 7. A comparison of parameters is tabulated in Table 1.

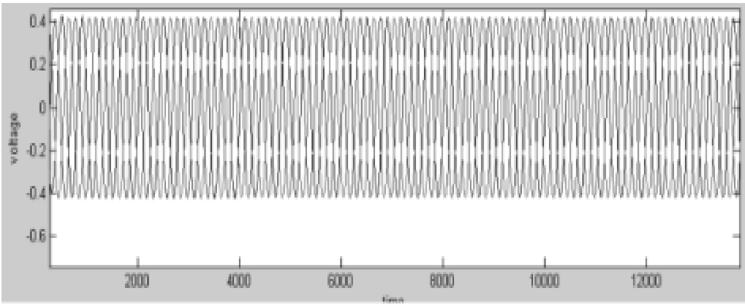

Figure 7. Load voltage with PI controller

In this figure 7 it shows the graph of time vs load voltage with compensation (PI controller).We can observe from the figure that the voltage variations is very small when we compare with without compensation, the harmonics are reduced .

Table 1. Comparison of Parameters

Parameters	Without PI controller	With PI controller
Reactive Power compensation	Unsatisfactory	Satisfactory
Performance under balanced and nonlinear loads	Contains desired harmonics	Reduced Harmonics
THD	38 %	15.12

Table 1. shows comparison of different parameters without and with compensation. In this table we can notice THD with compensation is reduced to 15.12 %.

IX. CONCLUSION

The demand for electric power is increasing at an exponential rate and at the same time the quality of power delivered became the most prominent issue in the power sector. Thus, to maintain the quality of power the problems affecting the Power Quality should be treated efficiently. Among the different power quality problems, voltage sag is one of the major one affecting the performance of Longwall Mining. PI controller is discussed to decrease voltage sag problem in Mining Industry. After the application of PI controller THD is reduced to 15.12 %.

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ISSN (Print) : 2320 – 3765
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BIOGRAPHY

Sukanth.T is pursuing Ph.D.in Mining Engineering, NIT Rourkela, Odisha, India. He completed his B.Tech (EEE) from Sree Visveswaraya Institute of science and technology, JNTUH in 2003, M.Tech.(Electrical Power Engineering) from Sree Nidhi Institute of technology and science, JNTUH, 2011.

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A. Jayalaxmi was born in Mahabubnagar District, Andhra Pradesh, on 07-11-1969,presently working as Professor in EEE Department and co-ordinator for Energy Studies, JNTUH. Hyderabad.She completed her B.Tech. (EEE) from Osmania University College of Engineering, Hyderabad in 1991, M.Tech. (Power Systems) from REC Warangal, Andhra Pradesh in 1996 and completed Ph.D. (Power Quality) from Jawaharlal Nehru Technological University College of Engineering, Hyderabad in 2007.