SIMULATION OF PI CONTROLLER TO IMPROVE VOLTAGE IN UNDERGROUND COAL MINE

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ABSTRACT

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 voltage at the equipment terminal determines the starting and running torques. Mining operation performance is strategically linked to the efficiency of electrical motors. In case of any typical underground mines starting a big motor such as is used on winders, crushers, haulers, pumps etc. particularly on weak systems, results in a large voltage drop, which significantly reduces the torque of the motor. The resultant harmonic currents cause high voltage distortions which in turn disturbs other equipment connected to the same bus, and can exceed harmonic limits issued by the utility. In such cases, fast dynamic reactive power compensation systems that reduce harmonics to acceptable levels become essential. Therefore loads such as continuous miners, shearers, crushers, etc. are in demand and also sensitive to voltage dips and fluctuations. In this paper, Custom Power (CP) devices is developed using MATLAB / SIMULINK and will be implemented for improving power supply to mining industry.

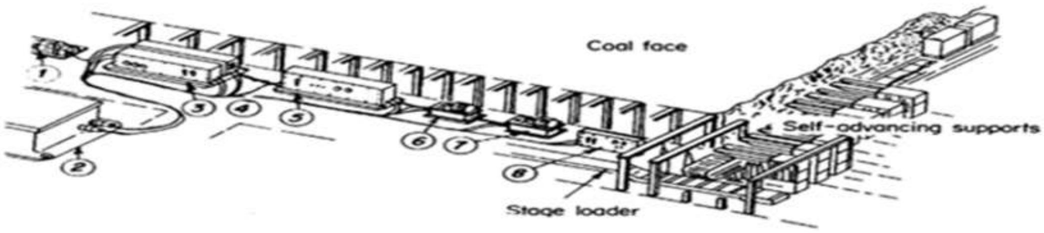
KEYWORDS: Power Quality, Mine, Loads, Custom Power Devices.

INTRODUCTION

Feeding safe and reliable power to mining complexes can be a challenging task. Operating a mine is a complex task which requires careful planning in order to secure a high availability of the equipment and a stable production rate without costly production outages. A difficult part is the mine's electrical network. The network needs to support various loads with different requirements on power quality. As mines get deeper, the need of voltage support becomes critical. The power or load centre is one of the most essential power-system units for underground mines. Underground mining machines are among the most compact and rugged. It requires a specialist with knowledge of both mining and electrical engineering. Its primary function is to convert the distribution voltage to utilization voltage for operating equipment throughout the mine. It must incorporate protective circuitry to ensure safe, efficient, and reliable operation.

The goal of the power engineer is to provide an efficient, reliable electrical system at maximum safety and for the lowest possible cost. Some mining machines have notoriously poor power factors resulting from underutilization of induction motors. Perhaps the most outstanding example is the continuous miner, which can have a power factor that averages 0.6 lagging during the operational cycle. Whether it is this machine or others that create excessive reactive power, the result is poor power-system efficiency and utilization. If the power factor is poor (under 0.80, for example), the utility company will attach a penalty to the power bill. Management should understand the advantages and disadvantages of one system over another, if the power system is poorly designed, not only will safety be compromised but the mine operator will pay for the resulting conditions with high power bills, high-cost maintenance, and loss of production. 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.



1. Motor, 125hp 2.100 KVA power centre 3.125-hp stage loader starter4. Dual 125-hp face conveyer starter 5. Dual 75-hp pump and 230-hp shear star6 .Pump, 75-hp 7.Pump, 75-hp 8. Master control

Figure 1. Power-system segment with LongWall equipment

A typical Longwall mining system as shown in figure 1 consists of several electrically operated components, interfaced with the coal-haulage system for the time. Cycle of face cutting includes cutting by shearer (Fig 1), setting of supports including face sprags (Fig 2a) and advance of supports. 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 2b shows Gate End Box with necessary circuit breaker, and other electrical safety devices for shearer operation in Long wall face at GDK 10A underground mine.

Figure 2a. Shearer cutting at Longwall face at GDK 10A underground mine

Figure 2b. Supports including face sprag in Long wall face at GDK 10A underground mine

Figure 2b. Gate End Box in main gate of a Long wall face at GDK 10A underground mine

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;

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

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].

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].

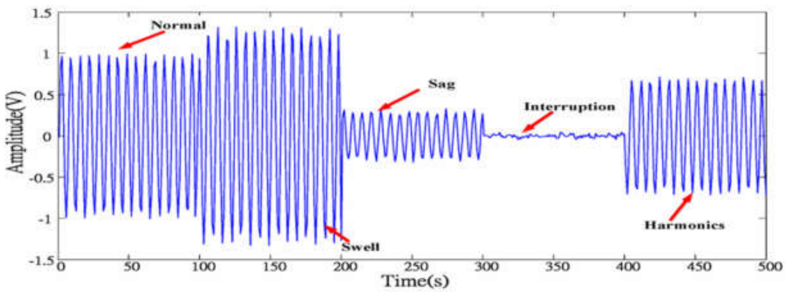


Figure 3. Power Quality problems

In the figure 3 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.

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 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].

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 4.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].

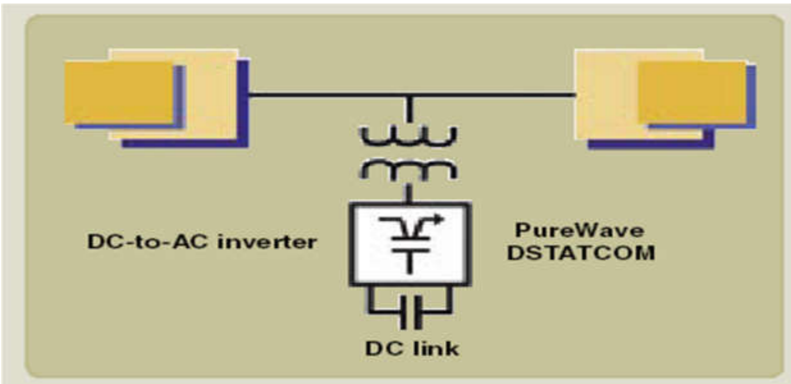


Figure 4. Basic block diagram of DSTATCOM

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

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.

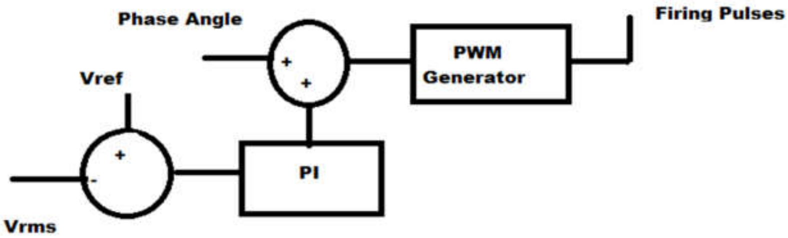


Figure 5. Block diagram of PI controller

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. Longwall Mining Layout of SCCL (GDK 10A) as shown in Figure 6, has input power of 1100 V and consist of two types of major loads i.e. two 375 K Shearer motor and four 250 KW AFC motors. 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. The torque of the motor decreases which indirectly affects the voltage and hence motor slows down.

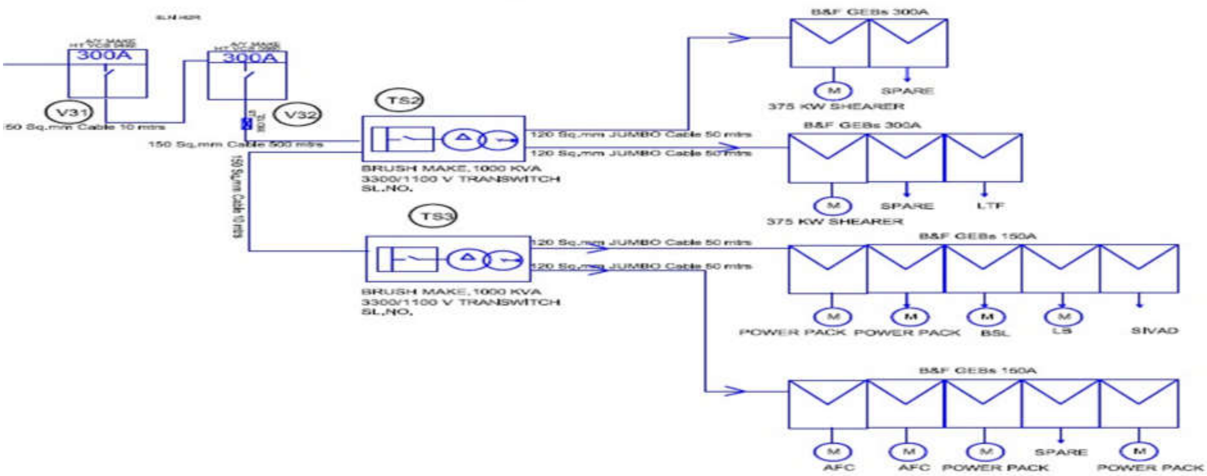
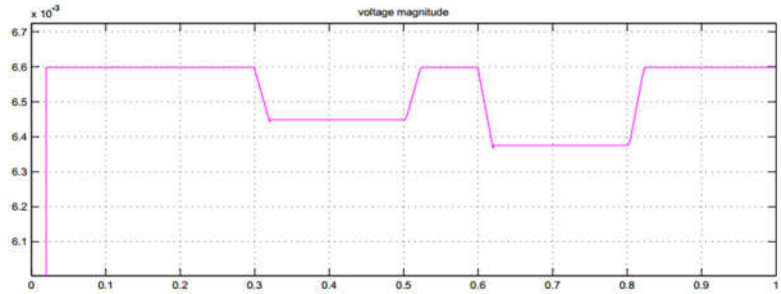


Figure 6. Electrical Layout of Longwall Mining at GDK 10 A mine, SCCL

The simulations are performed for the cases: (i) without compensation and (ii) with compensation. The system performance is analyzed. These cases are summarized below:

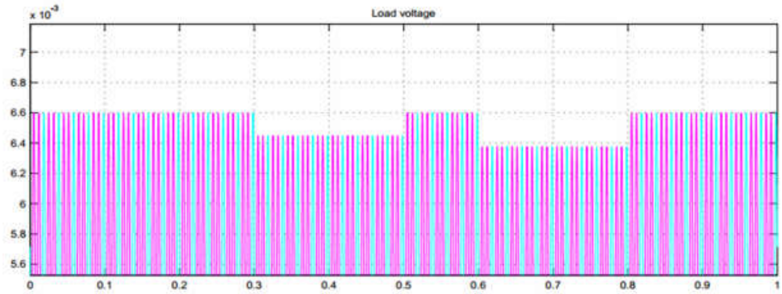
Case (1): Without compensation

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 7 (a) & (b). The Total Harmonic Distortion (THD) without compensation observed is 28 % at 50 Hz fundamental frequency which is high.



7 (a) Load voltage Magnitude

In this figure 7 (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.



7 (b) Load voltage

Fig. 7 (a) & (b). Simulation Result without PI controller

In this figure 7 (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.

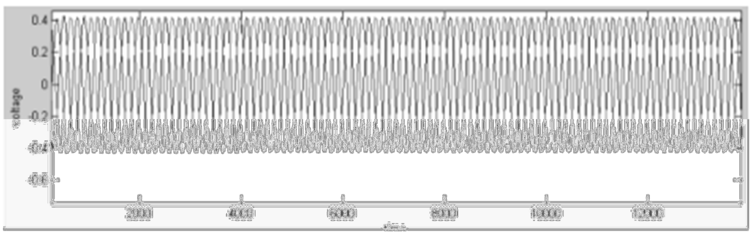


Figure 8. Load voltage with PI controller

In this figure 8 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. Shows comparison of different parameters without and with compensation. In this table we can notice THD with compensation is reduced to 15.12 %.

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

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 .Thus from the results we can conclude that by maintaining voltage at desired level we can reduce Power Quality problems by Custom Power Devices (CPD). Now-a-days poor power factor of electrical systems deployed in many mines, demands penalty due to low power factors. Therefore, simulation of electrical layout of typical mines and associated studies mentioned above will be highly beneficial to the mining industry by improving power factor, voltage sag and reduction of harmonics. PI controller is implemented to decrease voltage sag problem in Mining Industry. After the application of PI controller THD is reduced to 15.12 %.

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REFERENCES

1. L.C. Kaku "A study of Indian electricity rules, 1956 ", Lovely prakashan publishers.
2. A.M. Lloyd "Mine Power System" Information circular: 9258 Library of Congress Docs. no.: 128.27:9258, 1991
3. Gothelf Natan, Lennart Mukka, and Christian Payerl. "Dynamic Var compensation of mine hoists for improvement of power quality and increase of productivity at LKAB Sweden". 20th International Conference and Exhibition on Electricity Distribution-Part 1, CIRED, pp. 1-4, 2009.
4. R. Grunbaum and J. Rasmussen "FACTS for cost-effective improvement of power feeding of large mining complexes". IEEE International Conference on Energy and Control, pp. 1295-1300, 2012.
5. Arindam. Ghosh and F. Gerard. “Power quality enhancement using custom power devices ". Kluwer academic publishers, 2002.

6. T. Sukanth, D. Srinivas, M.Z. Lazarus and K. Pritam Satsangi "Comparative study of different control strategies for DSTATCOM" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 1, Issue 5, November 2012.
7. S. Jayanthu A Report on "Strata Monitoring in Longwall Panel no.3d1 & 3d2 of GDK.10A, APA, SCCL ", NIT Rourkela , 2013
8. Math H.J. Bollen "Understanding power quality problems". Vol. 3. New York: IEEE press, 2000.
9. Deshmukh, Shailesh M., Bharti Dewani, and S. P. Gawande “A review of Power Quality Problems-Voltage Sags for Different Faults". International Journal of Scientific Engineering and Technology, Volume 2, 392-3971, 2013.
10. Farhoodnea, Masoud, Azah Mohamed, and Hussain Shareef. "A comparative study on the performance of Custom Power devices for Power Quality improvement". IEEE International Conference in Innovative Smart Grid Technologies-Asia, pp. 153-157, 2014.
11. Anju Jacob, Babitha T Abraham, Nisha Prakash, Riya Philip, "A Review of Active Power Filters in Power System Applications ". International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, pp.2278 – 8875, 2014.
12. Muhamad, Mohd Izhwan, Norman Mariun, and Mohd Amran Mohd Radz. "The effects of power quality to the industries".5th Student Conference on Research and Development, SCORED. pp. 1-4. IEEE, 2007.
13. Ozerdem, Ozgur C., and Samet Biricik. "A research and solution proposal for reactive power problems in north Cyprus industries". IEEE International Conference on Electrical and Electronics Engineering. pp. 1-85, 2009.
14. Sridevi. J, J. Amaranth and G. Govinda Rao "Zonal Power Quality improvement using Static Var Compensator for an Indian Utility System" International Journal of Engineering Research, pp.1320-1325, 2012.