MITIGATION OF POWER QUALITY PROBLEM IN UNDERGROUND MINE USING DIFFERENT CONTROL STRATEGIES

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***Abstract*— Electricity plays a pivotal role in almost all businesses, particularly in the mining industry. Without it, it would be hard or nearly impossible for miners to do their job. But since mine sites are often located at the end of the grid and operated with the use of heavy mining equipment, they are particularly susceptible to power issues. With the constantly increasing cost of energy, mining sites are struggling to remain competitive in the market and keep their operation as smooth as possible. And since they are also considered very large power users, mines are usually being targeted by electrical companies and related organizations. As mines get deeper, the need of voltage support becomes critical. This paper presents the modeling and implementation of a three-phase DSTATCOM (Distribution Static Compensator) using different controllers such as proportional integral control and hysteresis voltage control to improve power quality in underground mining. The control technique based on voltage reference signals, and the proposed system is designed in MATLAB software, results show that the how DSTATCOM is useful for power quality improvement in underground mining.**

***Keywords*—** *Power Quality, DSTATCOM, PI Controller, Hysteresis Voltage Control, Underground Mine. Voltage Sag.*

I. INTRODUCTION

Power Quality may also be defined as "a set of electrical boundaries that allows equipment to function in its intended manner without significant loss of performance or life expectancy". In present day in power systems, major power consumption is due to reactive loads such as fans, pumps and induction motors. These loads draw lagging power factor currents and therefore give rise to reactive power burden in the distribution system. [1].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 equipment. 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. 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

Fig 1. Shearer cutting coal at Longwall face (GDK-10A MINE)

II. UNDERGROUND MINE POWER SYSTEM

Mine power system are different and also more complicated than traditional power system In mining industry underground mine power system are complicated than surface mines as shown in Figure 2.Because of the nature of the mine and its service requirements, distribution must almost always be radial the freedom in routing distribution enjoyed by surface mines is not available underground [2].

Fig 2. Shows Underground Substation [ALP]

The goal of the power engineer is to provide an efficient, reliable electrical system at maximum safety. 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.

III. 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 **.**

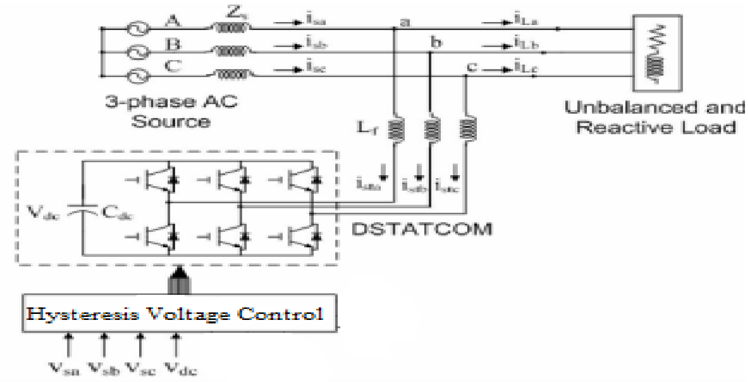

Fig 3. Schematics of a control system using DSTATCOM [6]

IV. CONTROL TECHNIQUES

The controllers used in this paper are PI (Proportional Integral) Controller and Hysteresis Voltage controller.

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. 4 shows the block diagram of the Implemented scheme.

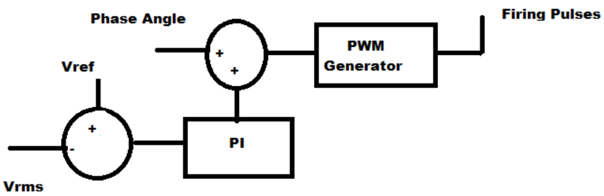

Fig 4. Block diagram of PI controlle

2.Hysteresis Voltage Controller

Hysteresis Band Voltage control is used to control load voltage and determine switching signals for inverter switches. which is shown in Figure 5.

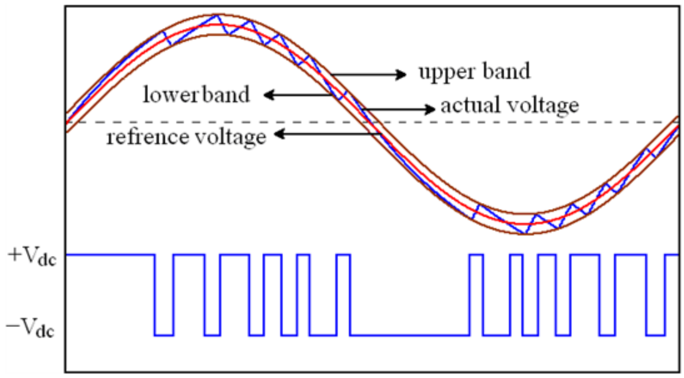

Fig 5. Hysteresis Band Voltage Control [5]

V. SIMULATION RESULTS

Electrical data has been collected from GDK-10A underground mine and Adriyala longwall project (ALP) underground mines respectively which is shown in Table 1 & 2 and based on the data collected, power system model has been developed in MATLAB / SIMULINK. 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 equipment. The simulations are performed for the cases: (i) without compensation and (ii) with compensation. The system performance is analyzed. These cases are summarized below:

Table 1. GDK-10A Electrical Ratings

S.No	Name of the Equipment	Rating		
		Power	*Voltage*	*Current*
1	Transformer (TS2)	1000 KVA	3.3 KV / 1100 V	175 A / 524 A
2	Shearer	375 KW	1100 V	300 A
3	Armoured Face Conveyor (AFC)	250 KW	1100 V	150 A

Table 2. Adriyala Longwall Project (ALP) Electrical Ratings

S.No	Name of the Equipment	Rating		
		Power	*Voltage*	*Current*
1	Transformer (TS2)	4.5 MVA	11 KV / 3.3 KV	236 A / 787.2 A
2	Shearer	855 KW	3.3 KV	2000 A
3	Armoured Face Conveyor (AFC)	855 KW	3.3 KV	2000 A

A. 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 to 9.The Total Harmonic Distortion (THD) without compensation observed is 28 % at 50 Hz fundamental frequency which is high.

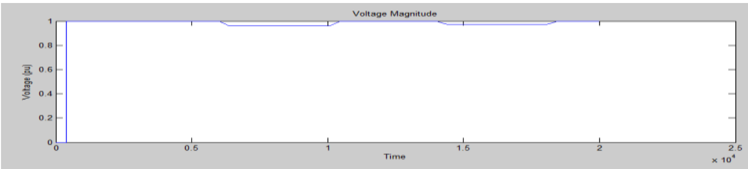

Fig 6. Three phase Load Voltage Magnitude (GDK-10A)

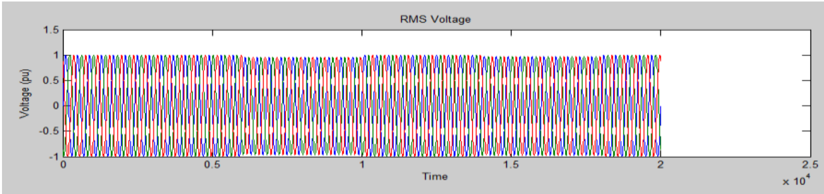

Fig 7. Three phase Load Voltage (GDK-10A)

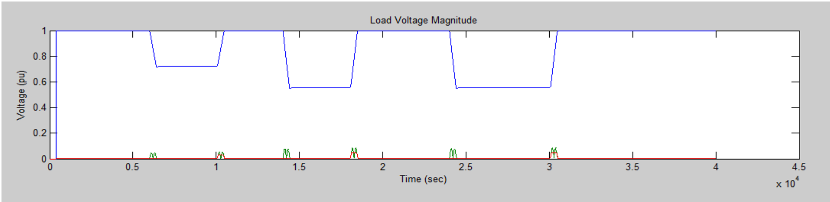

Fig 8. Three phase Load Voltage Magnitude (ALP)

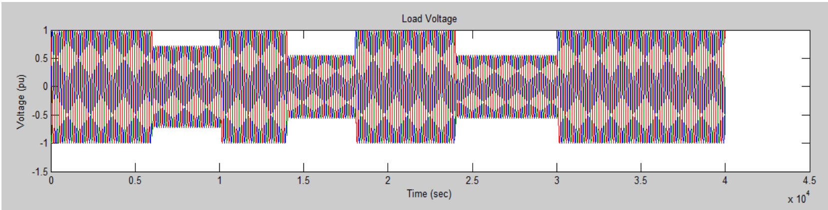

Fig 9. Three phase Load Voltage Magnitude (ALP)

Case (2): With compensation

1. PI controller results

After PI controller is added the results obtained from the simulation shows that the compensation offered by PI controller is much better than without compensation. The THD is reduced to 15.12 % and result is shown in Fig [10- 13]. A comparison of parameters is tabulated in Table 3.

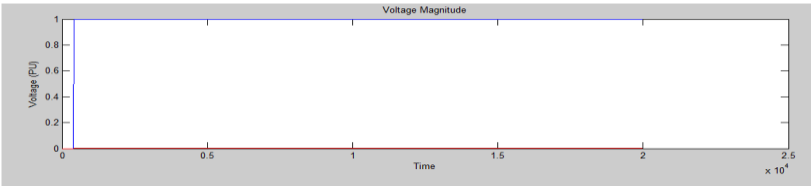

Fig 10. Three phase Load Voltage Magnitude (GDK-10A)

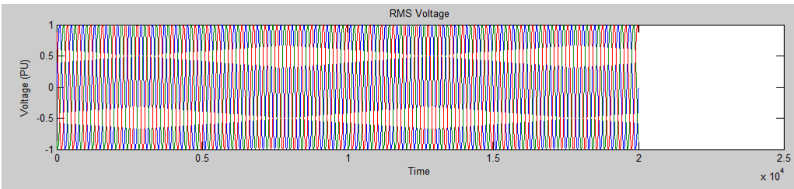

Fig 11. Three phase Load Voltage (GDK-10A)

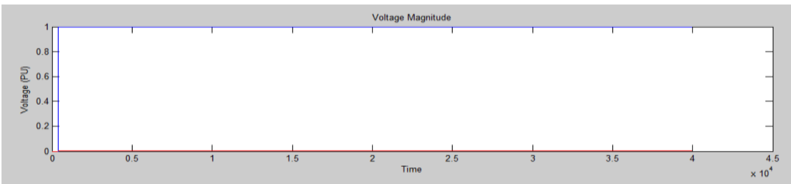

Fig 12. Three phase Load Voltage Magnitude (ALP)

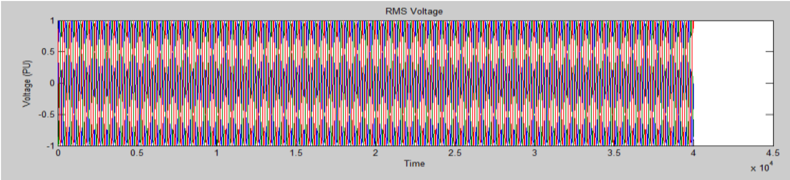

Fig 13. Three phase Load Voltage RMS (ALP)

2. Hysteresis Voltage control

After Hysteresis Voltage controller is added the results obtained from the simulation shows that the compensation offered by Controller is much better than without compensation. The THD is reduced to 10.12 % and result are shown in Fig [14- 17]. A comparison of parameters is tabulated in Table 1.

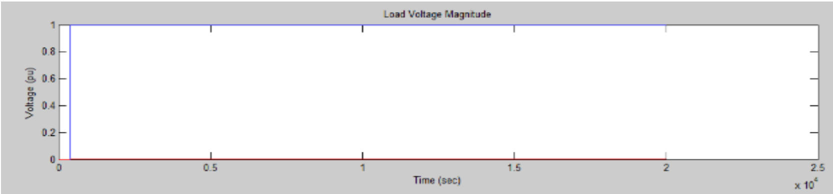

Fig 14. Three phase Load Voltage Magnitude (GDK-10A)

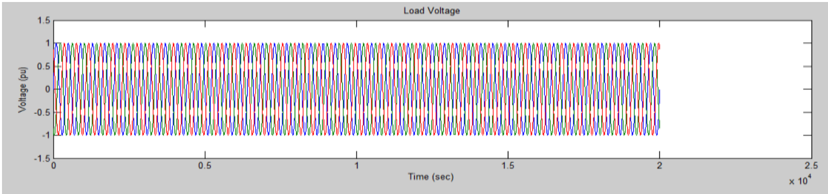

Fig 15. Three phase Load Voltage (GDK-10A)

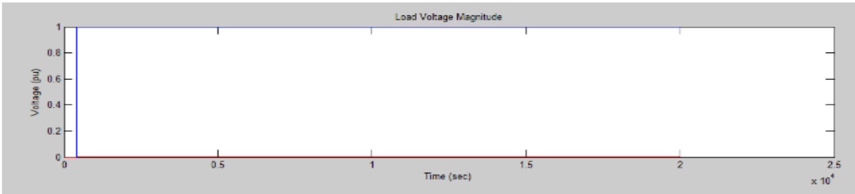

Fig 16. Three phase Load Voltage Magnitude (ALP)

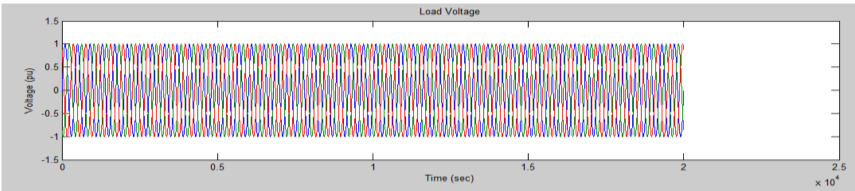

Fig 17. Three phase Load Voltage (ALP)

TABLE I. COMPARISON OF PARAMETERS

Parameters	**Without controller**	**PI controller**	**Hysteresis Controller**
Reactive Power compensation	Unsatisfactory	Satisfactory	Satisfactory
Performance under balanced and nonlinear loads	Contains desired harmonics	Reduced Harmonics	Reduced Harmonics
THD	28 %	15.12 %	10.12%

VI. 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 and hysteresis controller THD is reduced .This paper presented the design of PI and Hysteresis voltage controllers to compensate power quality problem in the underground mine. Simulation results of THD are compared for the cases without compensation and with compensation.

VII. REFERENCES

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