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POWER QUALITY IMPROVEMENT IN UNDERGROUND MINING USING DSTATCOM

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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 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. Voltage dips are considered to be one of the most severe disturbances in underground longwall mining. The major problem dealt here is the voltage sag .To solve this problem, custom power devices are used. One of those devices is the DSTATCOM (Distribution static compensator), which is the most efficient and effective modern custom power device used in power distribution networks. DSTATCOM injects a current in to the system to correct the voltage sag and swell. The proposed DSTATCOM is modelled and simulated using MATLAB/ SIMULINK software. In this paper Proportional Controller (PI) controller is implemented using MATLAB / SIMULINK.

Keywords: *Custom Power Devices, DSTATCOM, Longwall Mining, PI controller, Power Quality. Sag.*

1. INTRODUCTION

Power quality is one of major concern in the power system. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. 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. As per the Indian Electricity rules act 1956 in explosive areas transformers, including booster transformers are not allowed inside a mine [1].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 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 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 sensitive to voltage dips and fluctuations because these motors are Induction Motors. The torque of an induction motor is proportional to the square of the supply voltage. Therefore Voltage sag often causes equipment to trip, which in turn results in lengthy delays with resultant production and revenue losses. Voltage dips are considered to be one of the most severe disturbances in underground longwall mining. Fig 1 shows shearer cutting coal at longwall face in GDK-10A underground mine. 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. 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 "[2].

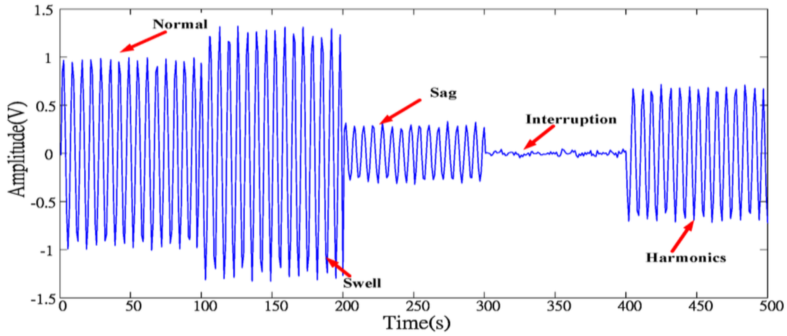

Fig 2. Power Quality Problem

Fig 2 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, harmonics etc.

III. 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 stand by generators) [2].

3.1. Basic Principle of DSTATCOM

A distribution static compensator (D-STATCOM) is the most efficient and effective modern custom power device used in power distribution system. D-STATCOM consists of a voltage source converter (VSC), a DC energy storage device (ESD), a coupling transformer connected in shunt to the distribution system through a coupling transformer. The VSC converts the DC voltage across the storage device into a set of three phase AC output voltages. 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

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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). Fig 3. 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 [3].

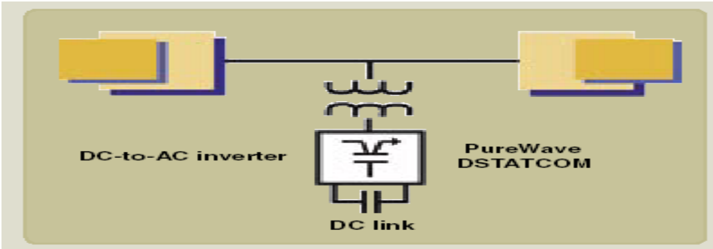

Fig 3.Basic block diagram of DSTATCOM

4. UNDERGROUND POWER SYSTEMS

Underground mine power systems have different characteristics from those for surface mines. As shown in Figure 4, 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 **,** the freedom in routing distribution enjoyed by surface mines is not available underground [3].

Fig 4. Underground Substation [ALP]

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 [4]. 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

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- Current-limiting capacity
- Selective-system operation
- Voltage regulation and
- Potential for expansion

V. PROPORTIONAL INTEGRAL (PI) CONTROLLER

The aim of the PI control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application, PWM methods offer a more flexible option than the Fundamental Frequency Switching (FFS) methods favoured in flexible alternating Current transmission systems (FACTS) applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses [5]. The controller input is an error signal obtained from the reference voltage and the value r.m.s of the terminal voltage measured. Such error is processed by a PI controller the output is the angle δ, which is provided to the PWM signal generator. It is important to note that in this case, indirectly controlled converter, there is active and reactive power exchange with the network simultaneously: an error signal is obtained by comparing the reference voltage with the r.m.s voltage measured at the load point. The PI controller process the error signal generates the required angle to drive the error to zero, i.e., the load r.m.s voltage is brought back to the reference voltage. PI Controller has the benefit of Steady-state error to be zero for a step input. Fig 5 shows block diagram of PI Controller.

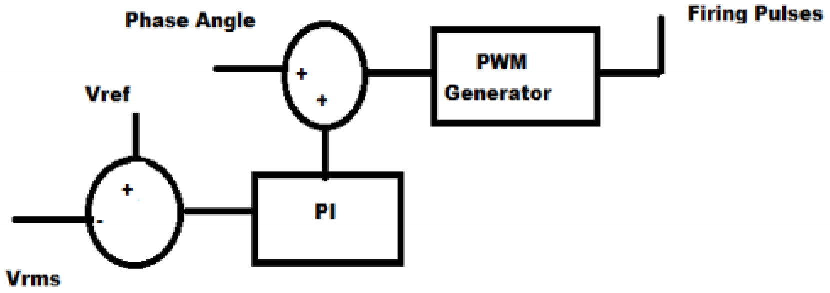

Fig 5. Block Diagram of PI Controller

VI. SIMULATION RESULTS

Electrical data has been collected from Adriyala longwall project underground mine. 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:

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6.1 Case (1): Without compensation

Model has been simulated for one second and load 1 (855 KW), load 2 (855KW) and load 3 (400KW) is switched on between 0.3 to 0.5 sec, 0.6 to 0.8 sec and 1.0 to 1.2 sec After switching ON the load, the voltage was falling down and decreased to a 0.9 PU. Simulation results are shown in Fig 6 (a) & (b). The Total Harmonic Distortion (THD) without compensation observed is 38 % at 50 Hz fundamental frequency which is high.

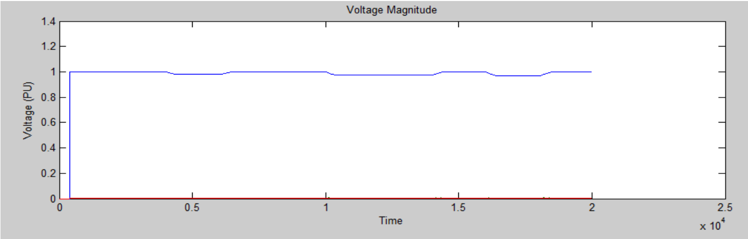

Fig. 6 (a) Three Phase Source Waveform (voltage Magnitude)

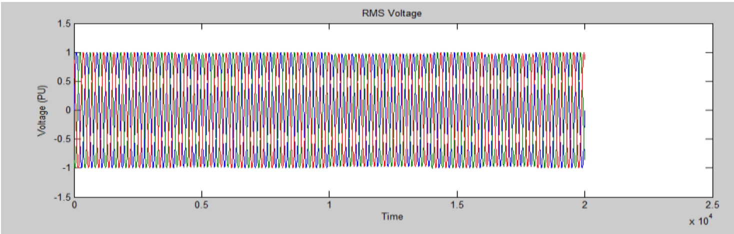

Fig. 6 (b) Three Phase Source Waveform (RMS voltage)

6.2 Case (2): With Compensation

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. 7(a) & (b). A comparison of parameters is tabulated in Table 3.

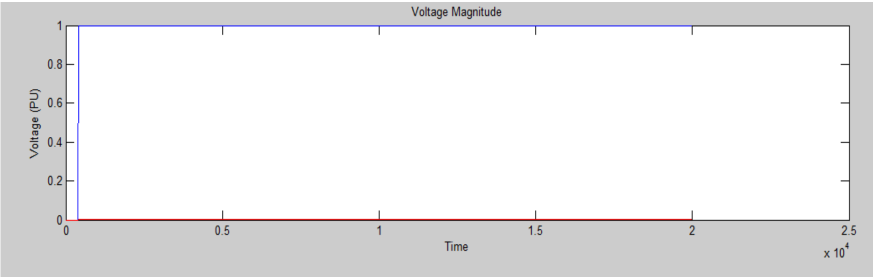

Fig. 7(a) Three Phase Source Waveform (voltage Magnitude)

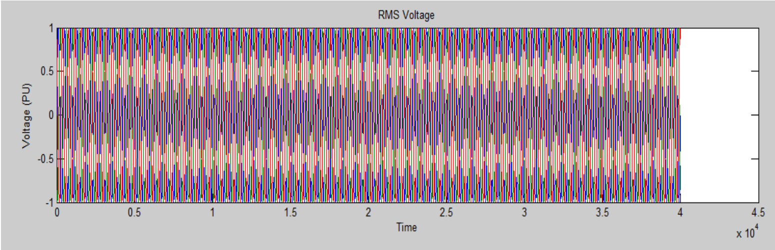

Fig. 7(b) Three Phase Source Waveform (RMS voltage)

Table 3. Comparison of Parameters

Parameters	Without controller	With PI controller
Reactive Power compensation	Unsatisfactory	Satisfactory
Performance under balanced loads	Contains desired harmonics	Reduced Harmonics
THD	28 %	15.12 %

VII. CONCLUSION

The modelling of test system for voltage sag without D-STATCOM gives the Total Harmonic Distortion (THD) 28% and with DSTATCOM (PI control) gives the THD 15.12%. Voltage dips are considered to be one of the most severe disturbances in underground longwall. 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 discussed to decrease voltage sag problem in Mining Industry. After the application of PI controller HD is reduced to 15.12 %. The proper use of this technology will benefit all the industrial, commercial and domestic customers with the following benefits continual energy efficiency, extended equipment life, reduced costs, reduced voltage fluctuations.

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