Digitally Integrating the Blast Design with Remote Wireless Electronic Blasting

by

Charles Pretorius
Delta Caps Product Manager
BME South Africa

Abstract

Electronic Delay Detonators (EDDs) with remote wireless programming and initiation capabilities have been successfully used for almost two years now. This system has been used in blasts mainly in South Africa, but also in South America and other countries in Africa.

Initially the industry was slow to accept the idea of remote programming and blasting. The advantages were not fully understood and there were some safety concerns. With close to 200 successful blasts as a reference, a much better understanding exists.

The advantage of such a system becomes even more significant when the programming of the detonators is digitally integrated with the blast design software as used by the Blast Engineer. It is now possible to import a survey file into the blast design software, to do the blast design using actual hole positions and to then export the designed firing times directly to the detonators down the hole via remote wireless communication.

Mines that have been exposed to this technology favour it to the extent that wireless centralised programming is becoming the norm against which other electronic delay detonator technologies are measured.
Introduction

This paper deals with EDD Systems as used in surface mines although many aspects are also applicable to underground applications.

When referring to the Electronic Delay Detonators, the abbreviation term EDD (singular) or EDDs (plural) will be used.

While EDD Systems have been in development for the past 20 years they have only been commercially applied during the last 10 years. During the last few years there has been a steady increase in the usage of EDDs, not only because the systems available have now reached an acceptable level of reliability, but also because the benefits of using EDDs is now much better understood by the market. There is still a lot of ignorance in the industry and a lack of understanding on how to evaluate EDD Systems and also how to realise the benefits obtainable from the use thereof.

The purpose of this paper is to explain some of the latest developments in EDD Systems. It also explains the basic principals of EDDs, the potential benefits of using EDDs, the main points that EDD Systems have in common and the major difference between various EDD Systems. It also provides the reader with a better understanding of how to evaluate EDD Systems.

Importance of Accuracy and Programmability of EDDs

It goes without saying that any EDD System has to be safe and reliable; it cannot be safe if it is not reliable. It should also be accurate. If it is not accurate is has no benefits over the cheaper alternatives other than the actual benefits achieved through its programmability.

*It is these last two attributes, namely being precise in its firing time and being programmable, which distinguish EDD Systems from other initiation systems and which are responsible for the vast and significant benefits obtained by using EDDs.*

In the design of the firing time of the EDDs, there are two important aspects to take into account, namely, the speed at which the stress wave travels and the rock response time, i.e. the time it takes for the rock to move and provide burden relief for the next hole. In the design of deck charges a third parameter becomes relevant, namely the velocity of detonation (VOD) of the explosives. It goes beyond the scope of this paper to deal with these aspects in detail but the parameters can easily be determined through field measurements.

The stress wave speed and rock response time are derivatives of the other rock characteristics such as rock density, uni-axial compressive strength and rock elasticity. These parameters are therefore indirectly taken into account.

The importance and relevance of accuracy and programmability are better understood if one considers that the speed of the stress wave through rock and that of the VOD of explosives are in the order of 5,000 m/s (15,000 ft/s), which is equivalent to 1 ms/5m (1ms/15ft).
If two holes or the initiation points of two explosive decks are between 5 and 10 metres (15 and 30 ft) apart, the time it will take for the stress waves to intersect with the adjacent hole or explosives deck will be in the order of 1 to 2 milliseconds. Therefore in order to have control on the interaction of stress waves, EDDs must be programmable in steps of 1ms with an accuracy of +/- 0.5ms as a minimum (especially in underground workings with holes in very close proximity).

The accuracy and programmability are also necessary to compensate for inaccurate drilling or variations in the burden of the front holes. How this can practically be done is explained later in this paper.

At this point it is important to briefly consider the accuracy of pyrotechnic delays in comparison to EDDs. A pyrotechnic shock tube (Nonel) system requires a down hole delay and a surface delay. The surface delay determines the delay between the different firing times of the blast holes, whilst the down hole delay ensures that the surface initiation system has progressed far enough ahead of the firing holes to prevent cut-offs and misfires due to fly-rock. Typical down-hole delay times are 350ms and 500ms with an accuracy of +/- 5%, that is +/- 17.5ms and +/-25ms respectively. Not even taking the inaccuracy of the surface delays into account this means that the minimum delay between holes, in case the one fires “late” and the other one fires “early”, must be 34ms and 50 ms respectively to ensure that the holes fire at least in the correct order (sequential firing). To allow for sufficient burden relief in accordance to the rock response times, the delays have to be even bigger. When using pyrotechnic delay elements it is therefore not possible to incorporate the dynamics of stress wave interference into the timing design.

The benefits of using EDDs

EDD Systems, due to their accuracy and programmability, have numerous benefits which need to be quantified and compared against the cost of the EDD System to establish the applicability of using EDDs. Some benefits will have a direct impact on the bottom-line profit whilst others will have to be quantified in terms of a discounted cash flow over the life of the mine. Due to this and because the benefits span across different business units, the decision-making must involve middle and senior management representing the various stakeholders.

Environmental impact. Vibration levels, fly rock and noise are better controlled with precise and programmable firing times. It allows for blasting in close proximity of built-up areas and other structures, which in turn could increase the reserves and extend the life of operations.

Fragmentation. Fragmentation, in terms of average size and size distribution, is more controllable and can either be increased or decreased. The amount of oversize, undersize and unwanted fines can also be reduced. As a result this has the benefit of better loading rates, crusher throughput, milling rates and ore recovery.

Slope stability. The better control of vibrations and back-break damage allows for increased slope stability. Not only does this reduce the risk of slope failures and but it actually allows for steeper slopes, deeper pits, a reduction in the amount of waste rock
to be mined and extends life of mine. Although the financial benefits are not always visible in the short term, the long-term financial benefits could be very significant.

Selective mining. EDDs make it possible to control the movement of the blasted material; waste and ore can be blasted in separate directions or the movement can be restricted. This assists selective mining, contributes to improved plant productivity, better utilisation of ore reserves and better ore quality control; all helping to improve the economic viability of the mining operation.

Flexibility and inventory. The fact that EDDs are programmable allows for flexibility. This will improve the reaction time to changed circumstances, reduce the amount of stock that needs to be carried and prevent stock from becoming obsolete or redundant. This is particularly true for remote sites with difficult logistical support.

Evaluating EDD Systems

Many potential users don’t really know how to evaluate different EDD Systems. The first mistake is to only look at the cost. In view of the benefits explained above, the appropriateness of an EDD system should be evaluated in relation to the benefits obtainable. Therefore the benefits must first be quantified and only then should the cost be considered.

A second mistake is comparative blasting. Comparative blasting does not serve much purpose; EDDs are only detonators and the end result depends on the design. The EDD system is a tool allowing you to optimise the design. Therefore, with the same design, the same delays and the same level of accuracy, the outcome should be the same.

What is important is the programmable capabilities and the accuracy. The accuracy can easily be determined by initiating representative samples on surface whilst measuring the actual firing times, which can then be compared against the designed firing time. The easiest and quickest way to do this is by means of seismic recordings, which are accurate up to 0,5ms. High-speed photography could also be used, but the accuracy is less than 1ms. VOD recordings are the most accurate however they are not always that easy to accomplish. The EDDs should ideally have an accuracy of +/- 0,5ms. Some systems have a fixed scatter around the nominal value whilst others have a scatter proportional to the nominal value.

The programmable capabilities are as important as the accuracy. Not only should it be easy to do the programming, but the system must also provide the user with the necessary means to optimise the blast design and to program the EDDs accurately and reliably according to the design. It is here where the different systems distinguish themselves from each other and this is the area where the potential user needs to make sure what he is getting.

The ease of use should include the ease of priming the holes, logging the ID of the EDDs and connecting the EDDs. A visit to operations that currently use the system would be an advantage.
Advanced features of an EDD System: Blast design packages

The latest development is for the suppliers of EDD Systems to develop blast design packages that will compliment their EDD System. They own the propriety rights to the system and will normally only make these software packages available to their EDD customers.

These software packages form an integral part of EDD Systems and provide the user with the necessary tools to optimise the benefits. The potential buyer should therefore familiarise himself with what these software packages offer.

Blast design packages should use all relevant information

Blast design software packages should be user friendly; they should provide the basic design capabilities but should also be capable of interacting with the mine’s existing planning and control systems and databases.

The aim is to optimise the end result of the blast in terms of fragmentation, rock movement, vibration, fly-rock, floor control, noise, back break damage and cost, while taking down-stream benefits associated with the loading, crushing, milling, ore recovery, slope stability and extended life of the operation into account.

The design parameters that have an influence on the end result and that should be taken into account are the amount and density of explosives (energy factor), the type of explosives (energy partitioning characteristics), the distribution of the explosives (burden, spacing, hole diameter, sub-drill, stemming and deck loading) and most importantly, the firing time of the different explosive charges. These are all controllable variables. There are also non-controllable variables.

The non-controllable variables that should be taken into account are the rock strength, normally quantified in terms of the uni-axle compressive strength, the rock density, the rock elasticity (Poisson’s ratio), the shock wave speed and the rock response time.

The packages should make use of the information contained within the mine’s geological model as well as all the relevant information related to the rock and ore properties that can be recorded during the drilling of the blast holes.

Blast design packages using actual hole positions

A design system that uses actual hole coordinates for the blast layout adds a lot of value to the outcome. The hole positions gets surveyed or picked up by GPS during or after drilling and are then mapped and used to optimise the timing design. Using actual hole positions makes it possible to compensate for inaccurate drilling, as well as for over burdened and under burdened front holes.

Another benefit of using actual hole positions is that it allows for the use of the relevant information contained in the mine’s geological model. Geological and geophysical information that has already been mapped can be superimposed onto the design using actual coordinates.
Blast design packages minimising vibration levels

A very important feature of EDD Systems is to minimise vibration levels. Therefore a careful evaluation of what the various systems can do in terms vibration control should be made. The most common practice is to minimise the amount of explosive per detonator, however it is more important to analyse the interaction of shock waves. If the stress waves from different holes coincide, resulting in constructive interference at the point of measuring, the effect is the same as the sum total of the explosives in these holes going off at the same time in a single hole. Conversely, to minimise vibration levels one should make use of destructive interference.

Picture 1.
A case study serving as an example of the shock wave interference analysis done for a blast at Dwarsrivier Mine on 14 September 2004. The blast consisted of 108 holes, 195 explosive decks with 10ms delay between explosives decks, 22 ms between holes and 41ms between rows. The timing was design to minimise the vibrations in the direction of the beneficiation plant, 100m (325ft) towards the south-east of the blast (bottom left corner).

Blast design packages: Accurate programming of the EDDs

Optimising the blast design in terms of all the input parameters, costs and desired outcome is one thing, but programming the detonators exactly and accurately according to the design is another. The bigger and the more complicated the blast pattern, the more of a challenge it becomes.

It is quite common for big surface mines to blast in excess of 500 holes at a time. The physical dimensions of such blasts are typically anything up to 500m (1,625ft) or more in length and between 50m (160ft) and 100m (325ft) in width. If the physical shape and drill pattern are irregular, as per the blast design layout below, one can easily get confused between the holes when walking on the block. Therefore, if the programming of the EDDs is done by walking from hole to hole and manually
programming them one at a time, mistakes can easily happen; either due to not being at the correct hole or by accidentally dialling in the wrong digits.

**Picture 2.**
The layout of a blast done at Rossing Uranium Mine on 25 September 2004. The case study illustrates the complexity and difficulty if programming of the EDDs has to be done manually by walking from hole to hole. Programming was done remotely from the point of blasting some 800m away. The block is 270m (8775ft) long and 65m (210ft) wide with a total of 495 holes. The hole positions are actual surveyed positions. It can be seen that holes are not always drilled in the planned position.

The problem of inaccurate programming of the EDDs is overcome by digitally transferring the delay times from the design to the EDDs in the field. One way to do this is to download the timing design from the PC (desk top or notebook) onto a handheld PC (terminal interface) from where it is then transferred to the EDDs down the hole. The system has the ability to verify that the design and the actual blast holes correspond. It is also flexible enough to allow holes to be added or deleted, or for timings to be changed in the field should the need arise.

**Centralised testing, programming and faultfinding.**

EDD Systems, where the EDDS are connected in series, allow for the automatic assigning of an ID to the EDD according to its position in the circuit (along the daisy chain). The programming of the EDDs can also be done from a central position because the series connection allows for one-on-one communication and programming; something that is not possible with parallel connected EDDs. The principle of a series connection therefore also simplifies the process of digitally transferring the firing times from the Blast Engineer’s design to the EDDs in the field.
Series connection also allows for establishing and identifying the exact position of a problem, for example a disconnected EDD.

**Verifying the correct programming and functionality of the EDDs**

It is important to ensure that all the EDDs are “alive” and functioning correctly. The following needs to be tested and verified; namely the allocated firing time, the digital clock and the calibration thereof, the capacitors and the fuse head. The more advanced systems are capable of two-way communication; the signals and data are sent out to the EDD and the EDD responds by confirming its functionality and confirming the information received. The correctness is then verified by the system.

**Remote testing, programming, arming and blasting**

Apart from the fact that some of the more advanced systems are able to perform the programming and testing of the EDDs from a central point, a unique feature is the ability to do this remotely from a central point, i.e. by means of some wireless communication media such as radio communication.

The actual loading of the capacitors can also be done remotely. An electronic hardware device that acts as a command interface is placed in close proximity to the blast holes. This instrument is hard-wired to the EDDs. All commands are then sent by radio from the blasting point to the interface, and then relayed to the EDDs. The interface also contains the energy needed to energise the EDDs.

The advantage of a remote system is that it does not require a blasting line between the point of blasting and the actual blast, which, apart from being very convenient, provides for safe blasting practices. This is particularly the case when performing blasts in deep open pits with steep benches, where finding a suitable spot from where the blast can be initiated could be problematic. In such cases it often happens that the blaster does not have a clear view of the blasting area. By blasting remotely the blaster is able to stand at a suitable blasting point from where the whole blasting area can be observed. The blaster then has the ability to visually make sure that the blasting area is safe before pushing the blast button.

Another important safety feature is that the system allows the blaster to stop and cancel the blasting process, including the disarming of the EDDs, at any stage before pushing the blast button.

Sufficient safety controls must be in place to ensure that no accidental initiation of any EDD can happen due to the interference of any other energy radiating sources, when using a remote system. This is achieved through proper encrypted and encoded communication protocol, ID identification and requests for appropriate passwords.

**Examples of mines making use of integrated blast design EDD Systems**

Attached, (Annexure A), for reference, is a list of some of the mines using an EDD System where the timing design is done on a PC and then digitally transferred to the EDDs down the hole. Programming, testing, arming and blasting is all done centrally.
and remotely over distances in excess of 1,000m (3,250ft) using wireless radio communication.

**Conclusion**

The advantages of making use of EDDs are great. EDDs offer a tool that can be used to reduce the environmental impact of blasting, to optimise blast results and to improve the productivity of all down stream activities, including the plant processes, minimising ore losses and increasing the life of the operation. It is therefore important that high level decision makers from all the relevant stakeholders should be involved in the decision-making process.

The selection of an EDD System that is safe, reliable, accurate and easy to use, and also provides the necessary means to optimise the design parameters, has the necessary control measures to ensure the correct programming and contributes towards safe blasting practices, is of the utmost importance.
### Annexure A

**Examples of mines making use a Digitally Integrated Remote Firing EDD System**

<table>
<thead>
<tr>
<th>Mine</th>
<th>Main reasons for using Electronic Detonators</th>
</tr>
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<tbody>
<tr>
<td>Rossing Uranium Mine</td>
<td>Fragmentation, Slope stability (vibrations), Protection of plant (vibrations)</td>
</tr>
<tr>
<td>Rio Tinto</td>
<td></td>
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<tr>
<td>Namibia</td>
<td></td>
</tr>
<tr>
<td>Potgietersrust Platinum Mine</td>
<td>Fragmentation, Slope stability (vibrations), Plant productivity, Extending life of mine</td>
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<tr>
<td>Amplats</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td></td>
</tr>
<tr>
<td>Sishen Iron Ore Mine</td>
<td>Fragmentation, Selective mining</td>
</tr>
<tr>
<td>Kumba Resources</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td></td>
</tr>
<tr>
<td>Optimum Opencast Coal Mine</td>
<td>Cast, dragline productivity, Blast in close proximity of national electricity power line</td>
</tr>
<tr>
<td>Ingwe, BHP Billiton</td>
<td></td>
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<tr>
<td>South Africa</td>
<td></td>
</tr>
<tr>
<td>Klipspruit Opencast Coal Mine</td>
<td>Cast, dragline productivity, Blast within 100m of National Highway a In close proximity of nearby village</td>
</tr>
<tr>
<td>Ingwe, BHP Billiton</td>
<td></td>
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<tr>
<td>South Africa</td>
<td></td>
</tr>
<tr>
<td>Sadiola Gold Mines*</td>
<td>Fragmentation, Selective mining (Not started yet)</td>
</tr>
<tr>
<td>Anglo Gold</td>
<td></td>
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<tr>
<td>Mali</td>
<td></td>
</tr>
<tr>
<td>Tati Nickel Mine*</td>
<td>Fragmentation, Protecting pit boundaries</td>
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<tr>
<td>Lion Ore Mining</td>
<td></td>
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<tr>
<td>Botswana</td>
<td></td>
</tr>
<tr>
<td>Nchanga Open Pit Copper Mine</td>
<td>Slope stability (vibrations), Extending life of mine</td>
</tr>
<tr>
<td>Konkola Copper Mines</td>
<td></td>
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<tr>
<td>Zambia</td>
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<tr>
<td>Dwarsrivier Chrome Mine</td>
<td>Fragmentation, Cast</td>
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<td>Assmang</td>
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<tr>
<td>South Africa</td>
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<tr>
<td>Lanex Chroom Mine</td>
<td>Fragmentation, Cast</td>
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<td>Samancor,</td>
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<tr>
<td>South Africa</td>
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*These mines have not yet started using the system at the date of this document (30 September 2004) but will have some experience by the date of presentation (February 2005).*