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Operational Risk monitoring and risk based decision making for aging equipment in the energy sector: two case studies.

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Ai miei nonni,

i cui frutti del loro amore

mi hanno donato

la vita…e la tenacia!

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Summary

Il seguente elaborato deriva da un lavoro di tesi all'estero condotto a Dublino presso il Dublin Institution of Techonology, la cui relatrice Chiara Leva mi ha permesso di collaborare con l'ESB Power For Generation company, il percorso è durato quasi quattro mesi.

Da questa esperienza nasce una consapevolezza che sta maturando soprattutto negli ultimi anni determinata a causa dei numerosi eventi che, durante l'ultimo ventennio, hanno costituito danni a livello mondiale: la necessità di incrementare il più possibile metodologie che garantiscano livelli di controllo e monitoraggio degli impianti sempre più all'avanguardia e piattaforme in grado di tener sotto controllo continuo parametri caratteristici delle apparecchiature più strutturalmente complesse, volti a garantire la sicurezza e il continuo scambio di dati tra varie stations.

La gestione e manutenzione delle apparecchiature inizia con la consapevolezza che l'invecchiamento non dipende da quanti anni ha l'apparecchiatura, ma riguarda ciò che è noto sulla sua condizione e i fattori che influenzano l'insorgenza, l'evoluzione e la mitigazione della sua degenerazione. Una volta che i sintomi dell'invecchiamento sono compresi e rilevati dall'ispezione, può essere presa una decisione su come procedere. Le opzioni possono includere la messa a punto di un caso per giustificare il servizio continuato, la nuova classificazione, la riparazione o la demolizione dell'apparecchiatura. Oltre agli aspetti di ingegneria, ci sono importanti questioni manageriali che dovrebbero essere prese in considerazione. La cultura aziendale e ruoli e responsabilità definiti sono discussi in relazione alla gestione delle attrezzature. Questi sono influenzati dalla quantità del personale, insieme a capacità, formazione e competenze. Viene inoltre evidenziata l'importanza di conservare le informazioni su documenti e le registrazioni durante la vita delle apparecchiature.

L'obiettivo principale di qualsiasi sistema di produzione di energia elettrica nel settore energetico basato su centrali elettriche è quello di fornire la quantità di energia richiesta dal mercato e far sì che questa sia conforme ai requisiti normativi definiti dalle leggi governative. Per raggiungere l'obiettivo, uno dei requisiti più importanti per qualsiasi sistema di produzione di energia è garantire la sua disponibilità tecnica in ogni momento. Questa caratteristica non è sempre facilmente garantita: durante il funzionamento, le apparecchiature più utilizzate vengono progressivamente deteriorate, fino a un certo punto di deterioramento, o altri tipi di guasti, come la fatica o la corrosione, che è sicuramente la causa più comune di guasti in questo settore, indotto dal particolare funzionamento tecnico dell'attrezzatura o dal suo stato di contatto continuo con agenti corrosivi.

Nuove opportunità sono offerte da sistemi monitorati in moderni impianti di processo, i cui dati devono essere integrati in DCS (sistemi di controllo distribuiti) e PLC (controllore logico programmabile) per la sicurezza, nei meccanismi nei materiali prima che l'integrità meccanica sia compromessa e, alla fine, prevenire potenziali risultati pericolosi. I dati acquisiti attraverso i sistemi automatizzati di monitoraggio e controllo, ma anche attraverso le ispezioni, sono fondamentali e saranno utilizzati per supportare il processo decisionale basato sul rischio e, infine, la gestione del rischio delle apparecchiature obsolete.

Apparecchiature colpite dall'invecchiamento: rischi ed opportunità

Quando l'attrezzatura è nuova e per la prima volta esposta alle sue condizioni di servizio, potrebbe verificarsi un tasso di variazione inizialmente maggiore rispetto a quello successivo. I giunti bullonati possono perdere e richiedere un serraggio poiché guarnizioni e guarnizioni di tenuta, valvole e pompe possono essere rigide finché l'usura non garantisce un funzionamento ottimale. Poiché gli impianti vengono portati online per la prima volta, potrebbe esserci un rischio maggiore di transitori operativi.

Le misure tipiche del danno sono il numero e la dimensione delle fessure o la perdita di spessore della parete. I tassi di degradazione possono essere molto variabili e non lineari a seconda del meccanismo di degradazione e delle condizioni locali. Mentre la perdita di spessore della parete dovuta alla corrosione può procedere ad un tasso costante (ma non sempre), il numero e la dimensione delle fessurazioni da creep e fatica e dalla corrosione locale tendono ad accelerare nel tempo. Tuttavia, possono esserci circostanze in cui il tasso di degrado rallenta o addirittura si ferma. Le aree corrosive possono creare uno strato di ossido che inibisce ulteriori attacchi. Le crepe da fatica possono smettere di crescere per un po 'se sottoposte a sovraccarico.

Le modalità di funzionamento, manutenzione, ispezione e riparazione possono influenzare fortemente il tasso di degrado. Il lavoro invasivo può introdurre contaminanti nel sistema e aumentare il tasso di degrado, sia temporaneamente che a lungo termine. L'ispezione, la manutenzione e le riparazioni appropriate delle aree danneggiate possono ridurre sia la quantità sia la velocità del danno, mentre il lavoro non necessario ha scarso guadagno.

Tipicamente, il danno accumulato e il tasso di degradazione aumentano con il tempo e quindi la probabilità che un singolo componente fallisca da questo danno accumulato normalmente aumenta nel tempo. Tuttavia, questa probabilità di guasto può essere modificata mediante ispezione, manutenzione e riparazione appropriate delle aree danneggiate. Il rischio di insuccesso oscilla quindi tra i 43 livelli di rischio operativo massimo e minimo, con la periodicità decrescente man mano che manutenzione, ispezione e riparazione diventano più frequenti più tardi nella vita.

Una valutazione del danno dovuta al degrado di tipici Power Plant prevede la divisione in due categorie: ci sono danni che cambiano direttamente il materiale dell'attrezzatura e altri che potrebbero impedire il corretto funzionamento dell'apparecchiatura. La necessità di introdurre la differenza nasce considerando che quest'ultimo e il suo modo di non minacciare direttamente l'apparecchiatura, in quanto, inoltre, problemi, come vibrazioni, fatica termica o corrosione, possono influenzare il funzionamento dell'apparecchiatura in un modo che alla fine diventa una minaccia all'efficienza dell'impianto.

I guasti agli impianti delle centrali a carbone, ad esempio, causati da cicli frequenti non sono eventi isolati, ma spesso si verificano in tempi imprevisti in tutto l'impianto. Molte delle modalità e posizioni di guasto non sono inaspettate, ma altre potrebbero sorprendere anche per un operatore di impianto esperto. La prevenzione di questi errori o la gestione dei tassi di errore è la chiave del successo. Un approccio per ridurre il danno ciclico è quello di modificare il limite di carico basso dell'unità per prevenire danni da ciclizzazione. Riducendo il limite di carico ridotto su un'unità da 750 MW a gas supercritica da 150 MW a 28 MW di notte, era possibile rendere redditizio il carico ciclistico giornaliero, ma non era un compito da poco. Le seguenti sottosezioni sono fornite per darvi un'idea dell'entità dei sistemi e dei componenti all'interno di una tipica centrale a carbone progettata per il funzionamento di baseload che sono interessati dal servizio ciclistico e da carico. Sebbene non siano elencati separatamente, anche i controlli sono interessati; alcuni impianti devono aggiornare i vecchi controlli analogici ai controlli digitali per migliorare la risposta ai controlli di generazione automatica forniti in remoto prima che siano in grado di effettuare il ciclo.

Metodi volti a prorogare la manutenzione delle apparecchiature

Questa sezione mira a confrontare alcune valutazioni del rischio tecnico, a sottolineare ciò che deve essere migliorato, ma principalmente a descrivere la percentuale di incertezza e imprecisione, che deriva da un calcolo e da una scelta processionale più spesso basata sull'esperienza tecnica, che invece richiederebbe un maggiore base teorica. La procedura deve essere eseguita da o con il supporto della persona competente pertinente e approvata dai rispettivi fautori.

Secondo lo standard europeo di manutenzione terminologica, la manutenzione è "la combinazione di tutte le azioni tecniche, amministrative e gestionali durante il ciclo di vita di un articolo destinato a trattenerlo o ripristinarlo in uno stato in cui può funzionare la funzione richiesta." È un insieme di attività organizzate che vengono svolte, con il minimo costo possibile, al fine di mantenere un articolo nella sua migliore condizione operativa. Tali attività, come la riparazione e la sostituzione, sono necessarie affinché un articolo raggiunga la sua condizione di produttività accettabile.

Il flusso di lavoro di manutenzione standard è rappresentato da una serie di passaggi sequenziali da seguire per ottenere un'operazione di manutenzione, dalle prime attività preparatorie, come le politiche di studio e di definizione, all'analisi una volta terminato il lavoro e all'azione da intraprendere per migliorare futuri casi simili.

Manutenzione e produzione dovrebbero essere interconnesse per ottenere il miglior successo nel settore. Ad esempio, gli obiettivi di manutenzione dovrebbero essere coerenti con gli obiettivi di produzione, come l'azione di mantenere le macchine e gli impianti di produzione nelle migliori condizioni possibili. Ogni apparecchiatura, in particolare nel settore, necessita di interventi di manutenzione per garantirne funzionalità, operabilità e sicurezza. Le attività di manutenzione vanno oltre quelle azioni, essendo anche direttamente interconnesse con ragioni legali ed economiche.

Il seguente metodo viene applicato all'analisi di tre casi studio in una company di produzione di energia elettrica in più punti della Repubblica d'Irlanda. Come parte di un processo continuo di miglioramento della sicurezza del processo, l'organizzazione ha identificato la necessità di anticipare l'identificazione, l'analisi e la gestione dei rischi in tutta le sue stations e di mantenere tali rischi in un format che facilitasse il confronto e il monitoraggio delle stesse. È stato quindi assemblato un team di progetto, con rappresentanti di diverse stazioni e specializzazioni, per creare un metodo di analisi del rischio in grado di soddisfare le esigenze di business.

Figure 1 - ESB Power stations (from https://www.esb.ie/our-businesses/generation-energy-trading-new/generation-asset-map)

Il primo esempio riguarda un mozzo del rotore del generatore in una diga (Coolkeeragh, ESB Power for Generations) Costituito principalmente da acciaio al carbonio tagliato a fiamma e presenta costruzione in saldatura. Il bordo esterno del rotore aveva una serie di laminati di acciaio accatastati su cui erano fissati i poli del rotore. I difetti che sono stati identificati sembrano essere in gran parte legati alla scarsa tecnica / procedura di saldatura durante la costruzione. Pertanto, il rischio consiste nel non valutare il potenziale difetto, causando guasti strutturali del mozzo del rotore in servizio, causando un impatto notevole come danni ai pali / statore del generatore e possibili lesioni al personale.

Il secondo esempio riguarda i miglioramenti che potrebbero essere ottenuti utilizzando un metodo più specifico e dettagliato, sottolineando le differenze tra l'approccio precedente. Ciò è dimostrato dallo studio di una stazione di valvola di bypass del modulo a turbina HP. Il fallimento in questo studio è stato il risultato di Solid Particle Erosion (SPE). L'origine delle particelle solide è la corrosione del rivestimento delle tubazioni ad alta energia, a causa dell'invecchiamento delle tubazioni combinato con un regime operativo che porta a un maggiore ciclo termico. L'aumento della durata tra le interruzioni / le opportunità di riparazione porta anche ad una maggiore esposizione agli effetti dell'erosione.

Dal momento che si è verificato l'errore è stato svolto qualche lavoro per mitigare il rischio di danni da SPE. Ad esempio, soprattutto modifiche fondamentali alle operazioni di avvio a caldo e freddo e monitoraggio di eventuali danni SPE. Dopo un adeguato confronto tra le varie opzioni, per ognuna di esse è stata effettuata un'analisi del rischio, la soluzione migliore è stata ottenuta identificando il rating di impatto, la sua probabilità e il suo rischio utilizzando le categorie supportate stimando una serie di rischi relativi alle opzioni che l'azienda sta affrontando per la riparazione e le conseguenze relative al rischio residuo.

Sebbene non vi siano rischi percepiti per la sicurezza del personale, un'interruzione forzata a lungo termine avrebbe enormi implicazioni finanziarie, principalmente dovute alla necessità di riparare l'unità, che ha un tempo aggiuntivo per fabbricare un nuovo modulo. Il rating di probabilità è stato selezionato come risultato del fatto che la SPE è generalmente una caratteristica nota su quelle unità, a cui deve essere aggiunta la consapevolezza dell'età della pianta, ma a volte potrebbe essere semplicemente causata da un'ispezione errata, che non ha t riportare il danno osservato. La potenziale azione di mitigazione è stata la ristrutturazione del modulo HP di riserva per ridurre la durata e l'impatto finanziario di un'interruzione forzata. Questa valutazione del rischio considera i rischi di danni alla ruota dell'impulso. Anche la disponibilità di un modulo HP di riserva è stata considerata un fattore in grado di influire positivamente sulla durata dell'interruzione.

Lo studio è stato condotto utilizzando considerazioni sul rischio monetizzato. Le opzioni disponibili sono delineate e valutate di seguito:

- Opzione A: sostituzione della stazione di valvole con aggiornamento del design per mitigare i problemi noti.

- Opzione B: sostituzione con la stessa valvola di design.

Dopo la valutazione del rischio per la situazione attuale, ciascuna opzione è stata scomposta nei costi effettivi degli interventi programmati più i valori monetizzati del rischio connesso all'intervento stesso; anche il rischio residuo rimasto dopo l'intervento è stato valutato.

È stata quindi calcolata una somma dei costi di valutazione del rischio considerando per ciascuna opzione la perdita di entrate direttamente proporzionale al periodo di tempo necessario per eseguire ciascun piano di intervento, i costi di riparazione effettivi, valutando tutti i componenti coinvolti come materiali, attrezzature, manodopera ecc. i costi di mitigazione che si riferiscono alle opzioni come ad esempio una sostituzione con lo stesso design, potrebbero essere ottenuti considerando il regime di manutenzione continua. E considerando le penalità prestazionali che potrebbero anche essere connesse con le opzioni (come l'incapacità di correre a piena potenza, ecc.)

È stato inoltre preso in considerazione un costo valutato in base al rischio per gli scenari possibili relativi alla salute, alla sicurezza e al rischio di sicurezza del processo connessi ai lavori di intervento pianificati (ad esempio lavori in quota ecc.). Nessuna simulazione o calcolo iterativo supporta questa valutazione in quanto richiede semplicemente un giudizio esperto dal team di gestione patrimoniale con un punto di ancoraggio appropriato per giustificare le stime scelte. Ultimo ma non meno importante, il metodo richiesto per valutare un valore di rischio monetizzato del rischio residuo rimasto dopo l'intervento attraverso il quale un valore delle prestazioni a rischio può essere successivamente aggiunto. Il vantaggio di rischio utilizzato per la definizione delle priorità delle opzioni è ottenuto semplicemente confrontando il vantaggio fornito dall'attuale esposizione al rischio meno l'esposizione al rischio residuo rispetto ai costi ottenuti dalla valutazione dei costi di valutazione del rischio dei vari piani di mitigazione come spiegato sopra. Più alti sono i benefici, migliore sarà la soluzione adottata.

Integrated Dynamic Decisioni Analysis, un differente approccio aziendale al calcolo del rischio

Con il termine “Integrated Dynamic Decision Analysis” (IDDA) - descritta da Remo Galvagni (1984; 1989) – si intende il software utilizzato in tale studio, che consente di portare avanti l'analisi del rischio in modo dinamico, tenendo conto degli eventi dipendenti dal tempo di processo, dell'ottimizzazione delle procedure per la manutenzione e il collaudo dei serbatoi GPL (Gerbec , Baldissone, & Demichela, 2016)

IDDA è un ambiente di calcolo per l'analisi della decisione dinamica integrata. Come strumento di analisi decisionale si basa su un'applicazione rigorosa della logica per definire e rappresentare tutti i possibili scenari alternativi incompatibili tra i quali deve essere fatta la scelta. Ogni scenario alternativo è sviluppato e presentato secondo un approccio logico Causa-Conseguenza. In questo approccio, le regole logiche e le valutazioni di probabilità sono applicate dinamicamente in quanto ciascuna informazione ricevuta progressivamente può essere utilizzata per definire il successivo percorso logico e le probabilità condizionali dei seguenti eventi, secondo una sana applicazione del ragionamento induttivo.

Il metodo IDDA si basa su una modellazione logico-probabilistica del sistema, integrata con la sua modellazione fenomenologica. Questo modello assembla un albero di eventi rafforzato, al fine di capire l'elenco dei livelli costruiti attraverso un'analisi funzionale del sistema, per creare un reticolo per l'indicazione dei livelli successivi che devono essere visitati, relativi a ciascuna risposta di soluzione, a assegnare un valore di probabilità a ciascun livello identificato, che rappresenta il verificarsi dell'errore atteso e, ultima operazione, per definire restrizioni logiche e probabilistiche, che possono consentire di adattare il tempo di esecuzione modificato del modello allo stato di consapevolezza corrente.

Chiaramente a tutto ciò va affiancato un modello fenomenologico che sia in grado di descrivere il comportamento fisico del sistema. Questo modello potrebbe influenzare lo status del modello logico andando a modificarlo descrivendo il comportamento reale del sistema, ovvero la sua risposta ad una eventuale casistica di danno, come quella che ad esempio potrebbe generarsi all'atto del malfunzionamento di un'apparecchiatura e come ciò impatta sulle altre, se l’impianto è in grado di reagire a tale problema, facendo sì che si riesca ad ovviarlo, oppure se è necessario uno shut-down dell'impianto stesso. In questo modo si garantisce una stima diretta della conseguenza per ogni eventuale sequenza, al fine di ottenere una stima del rischio, la valutazione del rischio complessivo del sistema e il valore atteso delle conseguenze.

Un buon punto di partenza per lo sviluppo del modello logico-probabilistico può essere un'analisi funzionale del sistema, sfruttando anche, ove disponibili, le informazioni contenute nell'analisi già portate avanti con metodologie tradizionali. L'ultimo caso di studio riguardava una procedura comune per la valutazione del rischio delle turbine a gas a rotore LP in cui la decisione era suddivisa in:

- Opzione 0: sollevamento del coperchio del modulo LP per ispezione, senza nuova acquisto di una nuova pala

- Opzione A: sollevatore del coperchio del modulo LP per ispezione, con una scorta di nuove pale (7 lame sono solitamente conservate, in base all'esperienza aziendale precedente)

- Opzione B: sollevamento del coperchio del modulo LP e sostituzione di tutte le pale.

- Opzione C: sostituzione blocco interno LP (rotori e trasportatori)

Ogni opzione ha un diverso workscope e costo, associato ad una valutazione del rischio basata sulla matrice del rischio, ottenuta attraverso un possibile valore dell'impatto e della similarità della soluzione adottata. In questo studio, è stato utilizzato un metodo ad albero dinamico degli eventi per calcolare la probabilità di rottura della pala della turbina a gas. Si basava su un'analisi di affidabilità strutturale per quantificare il comportamento di diversi componenti critici di strutture soggette a carichi incerti, condizioni limite e geometriche e parametri materiali. (H. R. Millwater, Y.-T. Wu, 1993) I modi di guasto della turbina sono generalmente descritti dalla frequenza, dalla corrosione sotto sforzo e dall'erosione, dall'affaticamento da creep; il calcolo della probabilità di fallimento richiede la selezione di una particolare condizione di stress, la durata del tempo.

L'elaborazione del modello logico-probabilistico, descritto nel file di input attraverso il software IDDA, restituisce tutte le possibili sequenze di eventi che il sistema potrebbe subire, a seconda delle conoscenze divulgate nel modello di input, insieme alle loro probabilità di accadimento. Nel modeling logica delle diverse opzioni, è stato considerato come vengono eseguite le procedure di manutenzione in base al numero di pale danneggiate.

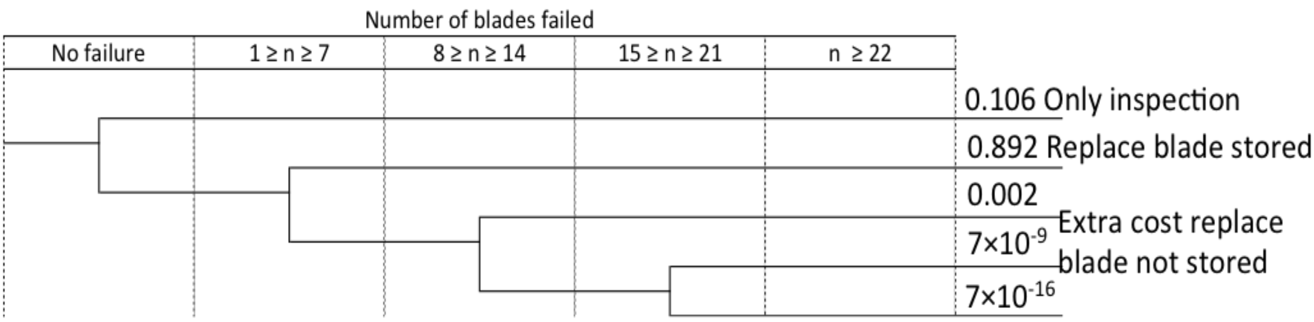


Figure 2 - Calcolo della probabilità di rottura attraverso IDDA (Opzione A)

Attraverso questo modello sono stati ottenuti i seguenti risultati: l'opzione 0 (nessun pezzo di ricambio immagazzinato) ha un rischio di 2023k €, che diminuisce a 1845k € per l'opzione A (7 lame memorizzate), poiché i pezzi di ricambio sono disponibili e nessun viaggio in stabilimento è richiesto più a lungo del previsto. Opzione Una modellazione conferma anche la decisione dell'azienda sul numero di blade da memorizzare, poiché il fallimento di 7 blade o meno è quello che mostra la maggiore probabilità di accadimento (circa il 99%).

Il rischio aumenta per le altre due opzioni: l'opzione B mostra un rischio di 3399k € e l'opzione C di 5799k €, poiché in entrambi i casi la sostituzione di tutte le pale (Opzione B) e anche dei rotori e dei vettori (Opzione C) coinvolge costi più elevati.

D'altra parte, queste ultime due opzioni hanno di conseguenza un'estensione del periodo di mantenimento: 8 anni per le opzioni B e C contro 4 anni per 0 e A Opzioni. Adattando così i valori di rischio al rischio di manutenzione annuale, si ottengono i seguenti valori:

L'opzione B con un valore di rischio di 425 k € / anno sembra essere la più conveniente, contro i 461 k € / anno dell'opzione A, 506 k € / anno per l'opzione 0 e 725 k € / anno per l'opzione C.

L'opzione C sembra essere in entrambi i casi meno conveniente, ma è opportuno considerare che il rinnovamento completo delle parti interne della turbina dovrebbe portare anche a un miglioramento della produttività dell'impianto, il che dovrebbe compensare i maggiori costi di investimento. Sfortunatamente, i dati sulla produttività non erano ancora disponibili quando questo documento è stato esteso, quindi il modello non tiene conto al momento di questo aspetto.

Dovremmo sempre cercare soluzioni ingegneristiche che siano quanto più precise possibile, perché, a differenza dei controlli più usuali, sono sempre presenti e prevedibili. Le fasi di progettazione di un progetto sono il momento migliore per implementare soluzioni ingegneristiche. Una volta che un sistema è stato costruito, è molto più difficile apportare modifiche e possono comportare un rischio più elevato e probabilmente inatteso. L'obiettivo di ridurre il rischio attraverso una buona ingegneria è di progettare sistemi che siano facili da usare senza errori. Questo deve includere tutte le modalità di funzionamento (ad esempio, operazioni normali, avvio / arresto e emergenza) e manutenzione. A livello più elementare si tratta di assicurarsi che le persone possano accedere a valvole, manometri, strumenti, punti di campionamento, ecc; prendendo in considerazione ciò che devono fare con questi articoli, compreso l'uso di strumenti e attrezzature. I principi di Task Risk Management ci consentono di andare oltre le considerazioni di ingegneria di base.

Electronic shift handover: un necessario step verso la digitalizzazione delle aziende

In quest'ultima sezione si focalizza l'attenzione sull'utilizzo di shift handover e su come questi possono garantire una corretta comunicazione tra gli operatori in modo da garantire l'affidabilità dell'impianto. Un breve excursus sui principali accident avvenuti dagli anni '80 sino ai giorni nostri, che possano fungere da esempio per sottolineare l'importanza di una corretta comunicazione tra gli operatori e di come questa sia "più sottile della lama di un coltello", di come un misunderstanding causato dalla rapidità di comunicazione o dalla superficialità umana possa generare catastrofi!

Figure 3 - Explosion at BASF Germany Plant (from https://financialtribune.com/articles/energy/51717/explosion-at-basf-german-plant)

Brazier & Pacitti (2008) hanno fornito un'utile revisione degli incidenti a causa della scarsa comunicazione e delle problematiche relative a Shift Handovers. L'esplosione a Bruncefield (Inghilterra, 2005), ad esempio, è stata causata principalmente da condizioni di monitoraggio ridotte e scarsa comunicazione tra gli operatori. L'operatore poteva monitorare il livello del serbatoio grazie a un misuratore, ma sfortunatamente un interruttore di alto livello indipendente (IHLS) avrebbe dovuto chiudere automaticamente le operazioni se il serbatoio fosse stato riempito eccessivamente.

Tuttavia, al momento dell'incidente il rivelatore di misura era bloccato e l'IHLS era inutilizzabile - non vi era quindi alcun modo per interrompere automaticamente l'operazione di riempimento e / o per avvertire il personale della sala di controllo che il serbatoio era troppo pieno (HSE, COMAH Competent Authority 2011) . Alla fine grandi quantità di benzina traboccarono, formando una nube di vapore che si accese provocando una massiccia esplosione. Un fattore che ha contribuito a rendere nota la relazione ufficiale è che il sito presentava tre condotte, e il personale della sala controllo aveva poco controllo su due di esse, soprattutto considerando le portate e il tempo di ricezione, quindi non c'era meno di informazioni ottimali per gestire l'archiviazione di combustibile in entrata, inoltre, si può notare dal rapporto come la conoscenza del danno sia stata fonte di confusione, in particolare durante il turno di consegna, causando un fraintendimento che ha contribuito a tale fallimento (HSE, COMAH Competent Authority 2011).

Il rapporto CSB dell'incidente di BP Texas City (rapporto di indagine CSB n. 2005-04-I-Tx Refinery Explosion and Fire, 2007) fa uno studio dettagliato con riferimento specifico ai fallimenti di comunicazione. Questo rapporto è utile per sottolineare la scarsa comunicazione tra i supervisori, in particolare per le informazioni critiche durante il passaggio del turno. L'operatore del turno di notte se ne andò presto, determinando una successiva breve e ambigua consegna del turno notturno che fu erroneamente interpretata dal turno in arrivo. Ciò è stato peggiorato dalla mancata registrazione dei passaggi completati nella procedura di avviamento da parte dei precedenti operatori di turno. Tutto ciò è stato esacerbato dal fatto che non vi era un chiaro requisito per la comunicazione tra i turni nello stabilimento BP. Pertanto, l'inchiesta ha rilevato che non sono stati scritti messaggi chiave, ma sicuramente trasmessi verbalmente per telefono, e questo è un evento che si verifica in così tante aziende, anche a causa della mancanza di un'adeguata piattaforma di condivisione o perché non c'è molta conoscenza a riguardo o non viene prestata un'attenzione adeguata all'uso di queste piattaforme. Ciò ha come conseguenza che la sala di controllo e gli operatori sul campo non hanno prestato la giusta attenzione a questo problema, chiudendo una valvola di controllo, mentre l'operatore sul campo stava aprendo manualmente lo stesso.

Il problema principale è stato causato dalla mancanza di comunicazione tra gli operatori, quindi una conoscenza errata di ciò che stava accadendo all'interno dell'impianto; ciò ha comportato un'azione errata da parte degli operatori nei confronti del gasdotto causando un malinteso tra l'operatore nella sala di controllo e il lavoratore in loco. Ciò ha provocato una successiva confusione. Inoltre, la particolare attività del gasdotto e dell'impianto come è causa in dettaglio una profonda comprensione del sistema, al fine di evitare equivoci come questo, al fine di minimizzare il potenziale errore umano. L'evento è avvenuto di notte, quando non ci sono lavoratori all'interno dell'impianto, ma solo individui nella sala di controllo, questo non ha permesso la consapevolezza di ciò che stava realmente accadendo, contribuendo a peggiorare il danno, o almeno non avendo la protezione per agire correttamente velocemente.

Sfortunatamente, questa non è una nuova scoperta. Nel novembre 1983 ci fu uno scarico accidentale nel mare di materiale liquido costituito da rifiuti radiativi prodotti da Sellafield Works della BNFL. Ciò è stato causato, come accertato dall'indagine dell'ispettorato delle installazioni nucleari, da una mancata comunicazione tra turni: un equivoco tra i lavoratori ha causato la scarica in mare di un serbatoio che si riteneva contenesse materiale idoneo per lo scarico in mare, ma in realtà conteneva materiale altamente radioattivo, creando un pericolo ambientale. È successo durante la normale manutenzione annuale in un arresto dell'impianto. (HSE 2006, b) La cosa più scioccante è che l'equivoco è stato causato dalla stessa etichetta che era sul serbatoio che riportava scritto "materiale reattivo", ma tra un passaggio e l'altro all'interno dell'azienda, il titolo è stato trasformato in "materiale non radiativo". Quindi, quello che prima era considerato materiale pericoloso, è successivamente trattato come una normale acqua di scarico. Ora è chiaro che con l'aumento dell'elemento tecnologico utilizzato in tutte le società del mondo, ci sono più controlli anche attraverso esperimenti tecnico-chimici, ma 30 anni fa non era possibile gestire tali errori, causando danni con un impatto.

Ultimo esempio, il Piper Alpha del 1988 (Scozia). Questo incidente è stato causato da una disattivazione di una pompa che non era in uno stato operativo. Come spesso accade, in cui viene rilevata un'inattività dopo che si è verificato un danno, l'inchiesta ha rilevato che non vi era comunicazione dello stato della pompa di condensa durante il cambio di turno. Inoltre, c'era anche un'incongruenza nei dati relativi a un serbatoio situato a valle della pompa che inviava i liquidi allo scarico, andando ad interessare anche la stessa problematica rilevata dall'impianto di lavorazione nucleare di Sellafield nel 1983, nel Regno Unito. (J. Ross, RISCHI 24)

Pertanto il progetto di tesi prevede un excursus sulle condizioni attuali di utilizzo degli electronic shift handover con successiva valutazione dei principali topic di cui devono essere costituiti, andando a fare una valutazione dei dati da riportare con evidenza e in che modo farlo.

Secondo lo studio condotto da Thompson & Plocher (2011), ogni shift dovrebbe registrare i seguenti dettagli:

1. Informazioni di base: data e turno, identificazione dell'impianto e nome dell'autore.

2. Informazioni sulla sicurezza: ogni evento incidente / vicino mancato o identificato ha un rapporto con le sue informazioni di base. Un evento imprevisto potrebbe causare un cambio di operatività dell'impianto. Inoltre dovrebbero anche essere registrate aggiunte o rimozioni di modifiche temporanee dell'impianto, simulazioni del sistema di controllo e / o override.

3. Informazioni ambientali: gli eventi che incidono sulle prestazioni ambientali devono essere documentati al fine di evitare guasti / incidenti che interessano l'ambiente e ridurre il rischio di trascurare alcuni parametri critici.

4. Informazioni sull'impianto: stato, riepilogo delle prestazioni e ordini di lavoro raccolti potrebbero identificare correttamente, ma soprattutto in tempo eventuali indicazioni che richiedono un'azione urgente e definire le conseguenze per la pianificazione dell'ispezione.

Circa il 60% -80% di tutti i guasti alle centrali elettriche sono legati alle operazioni di shift handover. Un'indagine su 215 impianti di produzione di vapore ha riscontrato molti problemi di attrezzature comuni: il più frequente è lo stress termico, seguito dalla corrosione e dall'induzione dell'acqua, altri problemi sono lo spostamento assiale, l'usura delle vibrazioni, lo stress centrifugo e il cooldown rapido. (Hesler, 2011)

Pertanto, in un registro elettronico è importante disporre di un rapporto transitorio, in grado di mostrare tutti i dati rilevanti per le apparecchiature interessate dal cycling: può essere necessario monitorare le condizioni cicliche e transitorie e le prestazioni delle condizioni dell'impianto.

Esistono tre diversi punti di ciclo a basso carico: il primo è il carico più basso a cui possono essere mantenute le temperature di progetto, il secondo include il carico basso pubblicizzato corrente e il terzo è il carico più basso a cui l'unità può rimanere in linea. Dopo questi tre bassi livelli ci sono tre cicli di accensione / spegnimento, che vengono definiti in base alle ore offline, con il peggior danno che si verifica durante un ciclo di avviamento a freddo. Mentre per l'avvio a caldo l'impianto può essere offline da 1 a 23 ore, l'avvio a caldo è dopo che l'impianto è stato spento tra le 24 e le 72 ore mentre l'avviamento a freddo si verifica dopo che l'impianto è stato più di 72 ore offline. La valutazione degli scenari seguenti ha costi di danneggiamento relativamente bassi, ma poiché ce ne sono così tanti, l'impatto cumulativo di molte operazioni che seguono il carico porta al danno di un hot start equivalente. È molto importante riconoscere, contare e classificare tutte queste operazioni secondarie di carico-carico, fino a considerare il carico che segue, c'è il carico minimo per un plat, dopo il quale è previsto l'arresto dell'impianto. Il primo passo per determinare i costi operativi è esaminare gli effettivi costi di manutenzione degli impianti convalidati e aggiungere il costo stimato del danno causato dai cicli in sé per sè.

Una volta esaminati i dati sui costi del ciclismo e definita la necessità di un modello finanziario dettagliato, è possibile delineare un elenco di componenti specifici che sono in genere influenzati negativamente dal ciclismo nel settore energetico e dai loro meccanismi di danno primario.

In una piccola e grande unità di carbone sub-critico, il primo elemento che più probabilmente mostra impatti negativi dal ciclismo è la caldaia e le sue componenti specifiche. Le testate della caldaia, ad esempio, sono affette da affaticamento e affaticamento da corrosione a causa di interruzioni dell'ossigeno e di avviamenti elevati o depositi chimici. I surriscaldatori e i riscaldatori della caldaia sono influenzati dal differenziale di alta temperatura e dai punti caldi dovuti a flussi di vapore bassi durante l'avvio, con conseguenti guasti di surriscaldamento a lungo termine. L'economizzatore è influenzato dal transitorio di temperatura durante gli avvii. Le turbine a bassa pressione sono tipicamente influenzate dall'erosione della lama. A volte i riscaldatori di acqua di alimentazione sono interessati dai costi della bicicletta, perché non sono progettati per rapidi cambiamenti termici. La corrosione da freddo e da cestello a bassi carichi e all'avviamento sono i principali meccanismi di danneggiamento dei riscaldatori ad aria; inoltre, il trattamento dell'acqua è influenzato dal ciclismo, specialmente nelle richieste massime di approvvigionamento di condensa e controllo dell'ossigeno. Il sistema di alimentazione o i polverizzatori sono interessati dal ciclo dei mulini, che può verificarsi anche solo dal carico dopo l'operazione, poiché i tassi di usura del ferro aumentano dal basso flusso di carbone durante la rotazione al minimo.

È' chiaro che se tutti questi parametri sono costantemente monitorati, le prestazioni degli impianti giorno per giorno potrebbero essere migliorate e si potrebbe cercare strategicamente una migliore condizione operativa per limitare il danno causato dall'invecchiamento e posticipare la manutenzione, o almeno per definire requisiti di manutenzione e carico per l'apparecchiatura in base al suo stato e non a ciò che viene tipicamente fatto negli impianti.

Una rapida analisi delle cause alla radice è stata condotta in una società irlandese fornitrice di energia elettrica, valutando i propri rischi operativi registrando relazioni periodiche. Gli scenari di rischio identificati sono stati monetizzati, concentrandosi solo sui rischi che avevano una causa specifica correlata all'invecchiamento della pianta. L'età dell'impianto e / o le condizioni operative sono state evidenziate come la causa principale più comune che rappresenta circa il 45% dell'esposizione al rischio monetizzata riportata nel registro dei rischi. Andando ad un'analisi più dettagliata e valutando anche quali sono le cause dell'invecchiamento primario, si può affermare che l'esposizione al rischio monetizzato è di circa 13.726.525,80 €, pertanto le cause di fondo associate all'invecchiamento delle attrezzature sono del 63% primarie.

L'analisi presentata in questa dissertazione tenta di colmare il divario nella guida alla costruzione del passaggio al trasferimento digitalizzato descrivendo i risultati di un caso studio che ha evidenziato la necessità della piattaforma e in che modo la sua attività può ottimizzare le prestazioni dell'impianto. Uno dei principali problemi che si verificano nelle impostazioni della piattaforma è la mancanza di analisi dei dati, che è una caratteristica essenziale per il suo uso ottimale. Capire quali sono i viaggi principali, o quelli più comuni, da dove provengono, quali sono le attrezzature maggiormente coinvolte e quali condizioni operative dovrebbero essere evitate dagli operatori sono domande chiave che, se affrontate correttamente, possono davvero migliorare le prestazioni dell'impianto.

Per giustificare tali affermazioni, una panoramica tecnica e un'analisi dei dati vengono applicate a un caso di studio in una società di generazione di energia elettrica in più località della Repubblica d'Irlanda (ESB). Questo studio si propone di evidenziare gli allarmi e i viaggi che sono stati registrati prima e dopo la prima distribuzione dei registri operativi

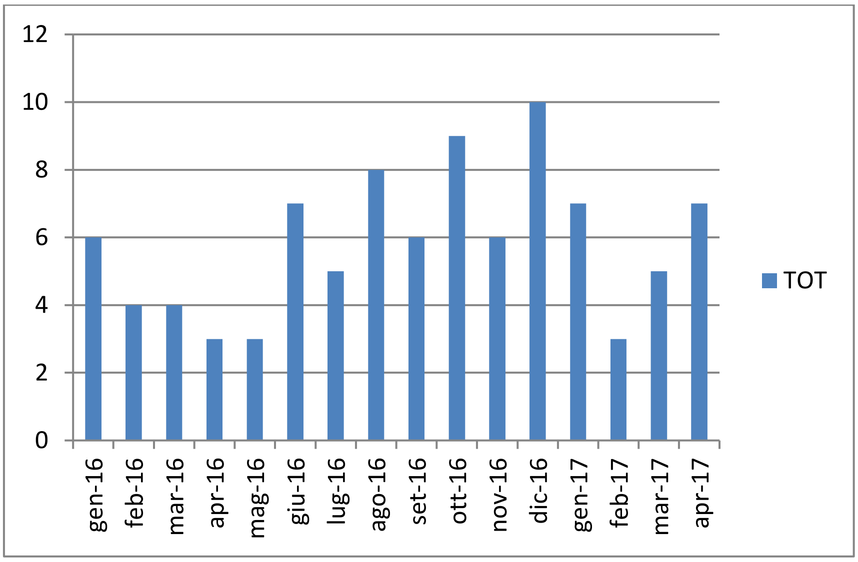


Figure 4 - Station Signals Analysis

L'implementazione iniziale dello shift record è iniziata ad aprile 2016. L'effetto immediato del registro di turno è stato un aumento del livello di dettagli e delle informazioni raccolte durante i trip. Il periodo che va da giugno a novembre 2016 coincide con il periodo in cui le opere di revisione e i progetti sono in esecuzione in tutte le stazioni, pertanto è normalmente associato ad un aumento della quantità di trip associati agli impianti. Tuttavia, a partire da gennaio 2017, la quantità di trip è diminuita considerevolmente mantenendo un livello più elevato di informazioni e controllo sulle cause di trip e sui problemi correlati su base giornaliera.

Come parte del piano di miglioramento della sicurezza del processo dell'azienda, è in atto uno sforzo costante per supportare il trasferimento coerente ed efficiente di informazioni di sicurezza, operative e commerciali tra i turni operativi e il registro dei rischi. Questo sforzo mira a ridurre il potenziale di incomprensione o la mancata segnalazione di eventi tecnici o commerciali legati a rischi noti che l'azienda desidera mantenere in condizioni di monitoraggio ravvicinate e la possibilità di aggiornare dinamicamente tali rischi riesaminando i problemi derivanti da incidenti operativi ricorrenti o possibili preallarme a causa di difficoltà nel mantenere le condizioni operative entro i limiti richiesti. Nel passaggio digitalizzato, infatti, il registro richiederà la registrazione di anomalie operative, tra cui: domanda su sistemi di sicurezza, sconvolgimenti, insufficiente disciplina operativa, procedure non seguite, quasi incidenti, ecc. Come incidenti di livello inferiore, che possono essere poi analizzati e migliorato. Ciò può anche essere utile per migliorare un feed live bidirezionale tra un registro operativo e il registro dei rischi poiché il registro dei rischi può fornire una panoramica dei principali scenari di rischio aziendali rilevanti per le operazioni, ma dall'altra parte il registro operativo può fornire informazioni per verificare come tali rischi possano effettivamente influenzare le pratiche operative e introdurre nuovi potenziali rischi sulla base delle deviazioni osservate dalle gamme di progettazione raccomandate.

L'obiettivo è trovare il giusto equilibrio tra ciò che è vantaggioso da un punto di vista del “market demand” e garantire le buone pratiche in termini di sicurezza per le operazioni quotidiane.

1. Introduction

No one can contend against the significance of security in process plants. These complex and regularly unpredictable conditions house an assortment of potential perils — putting the two individuals and physical resources in danger. In any case, despite the fact that organizations maintain wellbeing as an esteem, mischances keep on happening. Organizations must recognize and comprehend the underlying drivers of mischances keeping in mind the end goal to dispense with them. Most importantly, we should consider how practical is dispose of working environment mischances. Some may accept that mishaps are an innate piece of any procedure plant and that administration's part is to relieve the harm. This receptive attitude will never take care of wellbeing issues — yet with a proactive way to deal with plant security, all mischances are totally preventable. By taking out mischances, organizations can secure the wellbeing and strength of their representatives, limit exorbitant harm to apparatus and broaden the life of their benefits. At the extremely essential level, machines are replaceable; individuals are definitely not. Also, unexpectedly, similarly as human security is an essential hazard when machines fizzle, while human mistake is an essential driver of machine disappointment.

Providing the measure of vitality requested by the market and conforming to the administrative prerequisites characterized by government laws is the principle target of any electric power age framework in the vitality segment in view of energy plants. Hardware maturing is an unavoidable truth in control frameworks in spite of the fact that there might be diverse reasons for maturing for various kinds of gear. The immediate outcome of hardware maturing is higher framework hazard because of higher disappointment likelihood and conceivable framework harm following the finish of-life disappointment. Utilities ordinarily do deterrent upgrades and general assessments. Support exercises can, to some degree, broaden the life of gear yet could be expensive for hardware at their finish of-life organize, so it's smarter to discover and consider a bargain amongst upkeep and substitution that must be precisely arranged. The thesis shows a survey of conceivable distinctive strategies and their reasonableness for viable appropriateness in the vitality division for an organization overseeing power stations.

Organizations can apply hazard based basic leadership and operational hazard checking through an appropriate Asset Management utilize, which can empower an association to acknowledge an incentive from resources in the accomplishment of its hierarchical destinations. What constitutes esteem will rely upon these goals, the nature and reason for the association and the requirements and desires of its partners. Resource administration underpins the acknowledgment of significant worth while adjusting money related, natural and social costs, hazard, nature of administration and execution identified with resources. The benefit administration framework gives data to help the advancement of advantage administration designs and the assessment of their viability. Resource data frameworks can be amazingly expansive and complex in a few associations, and there are numerous issues engaged with gathering, confirming and solidifying resource information keeping in mind the end goal to change it into resource data. Making, controlling, and archiving this data is a basic capacity of the benefit administration framework. Open doors for development can be resolved specifically through checking the execution of the benefit administration framework, and through observing resource execution.

Thanks to this overview, the use of existing and a proposed customised methods will be discussed on the basis of some concrete examples of application.

Furthermore, the second case study was based on companies reports, aiming to underline the necessity of a proper use of electronic shift handover and how they can be settled in power plants in order to facilitate understanding and collaboration among operators. During the operation of a plant, a large number of events occur that need to be documented. In addition, operators have to document what actions are being performed. This documentation is obligatory in many plants. In the past, this was usually done in paper form, with all the consequences related.

Failures in shift communication, including shift handover, continue to be a significant contributor to industrial major accidents worldwide and are now increasingly recognized as critical in other domains such as patient safety. The electronic shift book program automates this time-consuming procedure: each component can be assigned certain binary signals that automatically generate a shift book entry in the case of an event, avoiding the dispersal and preservation of data through a proper use of these.

This study was conducted thanks to the collaboration with the Dublin Institute of Technology, applying the practical case study in an Irish electricity supplying company, the ESB. It offers an overview of upcoming tools/methods, focusing in particular on specific examples and the criteria to be used for aging equipment and the benefits to be achieved.

2. Aging equipment in energy sector, risk and opportunities

In this new era, in which asset managers are compelled to continue operating aging assets while deferring maintenance and investment. The consequences of such decisions are rarely immediate, deferring maintenance and investment will often result in the desired outcome (cost reduction) in the short term, further reinforcing the practice order to set up a "intelligent prognostics" system, which can measure, control, and alert the operating personnel, detecting degradation. (W. McNett, 2016)

Approaching the issues above described requires a better control the ageing equipment, to quantify the impact of operating modes on system reliability, to accurately estimate their residual life and to adapt the maintenance strategy, while respecting safety, regulation and operational performance.

The management of equipment begins with an awareness that ageing is not about how old the equipment is, but is about what is known about its condition, and the factors that influence the onset, evolution and mitigation of its degradation. Once the symptoms of ageing are understood, and detected from inspection, a decision can be made how to proceed. The options can include putting together a case to justify continued service, re-rating, repair, or scrapping the equipment. In addition to the engineering aspects, there are important managerial issues that should also be considered. The company culture and defined roles and responsibilities are discussed in relation to managing equipment. These are affected by staff demographics, along with skills, training and competencies. The importance of maintaining documentary information and records throughout equipment life is also highlighted.

The main objective of any electric power generation system in the energy sector based on power plants is supplying the amount of energy demanded by the market and complying with the regulatory requirements defined by government laws. To attain the objective, one of the most important requirements for any power generation system is to guarantee its technical availability. This feature is not always easily guaranteed: during operation, the equipment that are used the most are gradually deteriorated, until some point of deterioration failure, or other types of failures, such as fatigue or corrosion, that is certainly the most common cause of failures in this sector, induced by the equipment particular technical operation or its continuous contact status with corrosive agents.

New opportunities are given by monitored systems in modern process plants, whose data have to be integrated in DCS (distributed control systems) and PLC (programmable logic controller) for safety, in mechanisms in materials before mechanical integrity is compromised and, in the end, prevent potential dangerous outcomes. Data gained through the automated monitoring and control systems, but also through the inspections, are fundamental and will be used to support risk- based decision making, and ultimately the risk management of ageing equipment.

In order to understand, identify, and manage aging or deterioration, it is necessary to develop mathematical models that represent the aging process to show the deterioration of power equipment, and determine the cause of aging. The first concept useful to describe the ageing equipment failures could be seen by the relationship between the equipment likelihood of failure over a period of time, which is represented by the well-known “bathtub curve”. The exponential distribution is usually used to model the probability of time to failure, or constant failure rates. (Haifeng Ge, 2010)

Thanks to a recent case study in a Power Generation Company in the Republic of Ireland was demonstrated that most of the 43% of the trip root causes was associated to Plant Age Causes, and 65% of that is related to primary causes. Although aging and deterioration effects are unavoidable, it is desirable to find a way to slow down the deterioration rate, and to extend equipment’s service life and this could be obtained reducing the environmental or operational agents that cause deterioration, as it can be shown in detail in Section 6.

The aim here is to present a risk-based deferred maintenance policy selection methodology for power plants equipment thanks to a proposed method based on risk analysis and decision-making concepts, eg. (Darabnia, Demichela 2013a) and (Darabnia, Demichela 2013b). The analysis that will be addressed is shown as the development of professional competencies, related to ageing management, and learning from the experience gained by the data collection and analysis. (E.C., 2010)

2.1 The probability of failure and the accumulated damage

By its tendency, modern gear containing risky as well as pressurized liquids is presented to states of pressure and condition that at last will corrupt the material texture from its underlying state. Harm will collect until the point when the gear achieves a state in which it is judged to be never again fit-for-benefit. Unless repaired or re-appraised, the hardware might be said to have achieved the finish of its life. As harm gathers, disappointment turns out to be progressively likely, and if not pulled back from benefit, disappointment or some likeness thereof will in the end happen.

The kind of gear and qualities of obligation can fundamentally impact the life. It isn't irregular for machines with moving parts to debase quickly and to have extremely constrained resistance to harm and deviations from the plan conditions as far as human mistake or varieties in process conditions. Static hardware, for example, process vessels and funnels, have a tendency to have considerably more noteworthy resistance, and under benevolent conditions, can stay in-benefit for a long time. As a rule, machines in the compound procedure enterprises have relatively a bigger number of disappointments right on time in life than static hardware. There is, be that as it may, an excessive amount of variety in the causes and rate of harm amassing, to be particular, and the life of various things can shift especially.

Notwithstanding when new, or after repairs, hardware may as of now contain assembling and establishment abandons that can be the seed for an expanded rate of debasement amid benefit. Welding deformities, cleft and poor fit-up and arrangement of parts are regular. Since things of hardware can be independently created, regularly with manual welding forms, there can be unmistakable varieties in quality between things of ostensibly a similar development. These varieties are tremendously decreased where there is great quality affirmation and quality control amid manufacture.

At the point when equipment is new and first presented to its administration conditions, it might encounter an at first more noteworthy rate of progress than further down the road. Catapulted joints may spill and require fixing as seals and gaskets bed-in, valves and pumps might be firm until the point when wear guarantees ideal running. As plant is expedited line out of the blue, there might be a more serious danger of working homeless people.

Run of the mill measures of harm are the number and size of breaks, or the misfortune in divider thickness. Rates of debasement can be exceedingly factor and non-straight relying upon the corruption component and the neighborhood conditions. While divider thickness misfortune because of consumption may continue at a consistent rate (however not generally), the number and size of crawl and weakness splits and neighborhood erosion have a tendency to quicken with time. There can, be that as it may, be conditions where the rate of debasement moderates or even stops. Eroding territories can develop a layer of oxide that represses additionally assault. Exhaustion splits can quit developing for some time if subjected to an over-burden.

The way of activity, support, examination and repairs can unequivocally impact the rate of corruption. Obtrusive work can bring contaminants into the framework, and increment the rate of debasement, both briefly and in the more drawn out term. Fitting examination, upkeep and repairs of harmed zones can decrease both the sum and rate of harm, while superfluous work has little pick up.

Ordinarily, collected harm and corruption rate ascend with time, (Fig.3), and subsequently the likelihood that an individual part will fall flat from this aggregated harm typically ascends after some time. In any case, this likelihood of disappointment can be changed by proper assessment, upkeep, and repair of harmed zones. The danger of disappointment at that point sways between the 43 greatest and least working danger levels, with the periodicity diminishing as upkeep, assessment and repair turn out to be more incessant further down the road (Fig.4). Fig.5 demonstrates a model (bath) bend for the likelihood of disappointment from corruption for a vast populace of gear instead of a solitary thing. In these figures, the life is appeared in Stages.

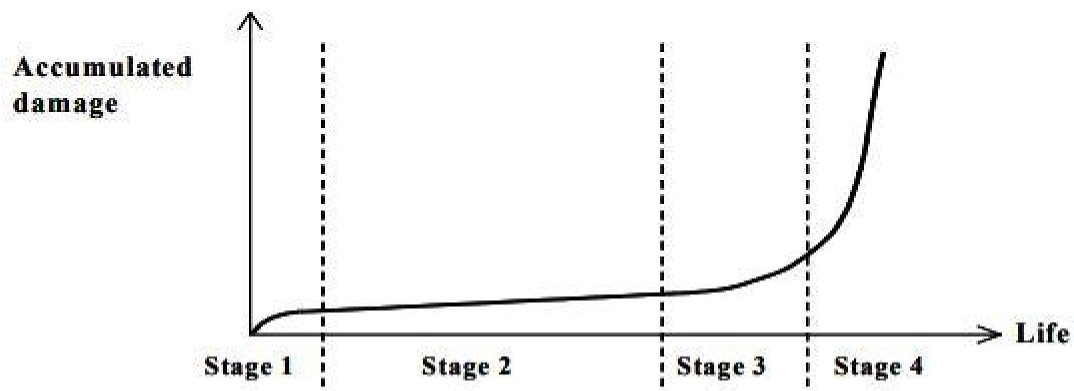


Figure 5 - Variation of accumulated damage during equipment service

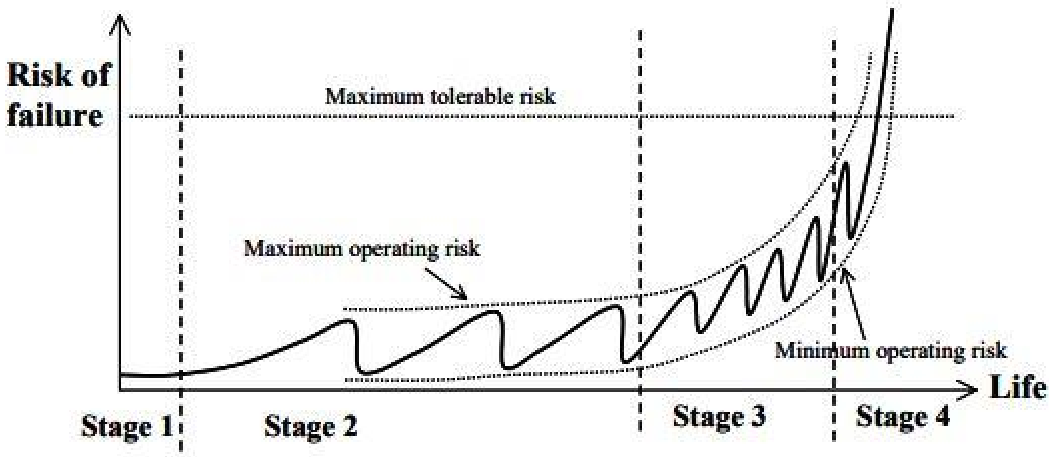


Figure 6 - Effect of periodic maintenance, inspection and repair on the risk of failure for a piece of equipment, each saw-tooth represents an inspection being carried out

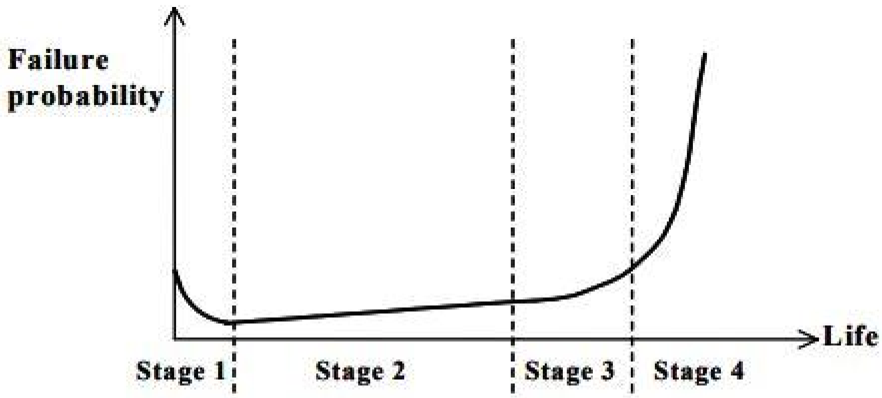


Figure 7 - Model for the probability of failure of a population of equipment

2.1.1 The Four Stages Of Equipment Life

For the reasons for lifecycle administration, it might be useful to think about a thing of hardware as having four Phases throughout its life, each with specific qualities and having an alternate administration, investigation and support system. These Stages might be considered as:

- Stage 1: Post Commissioning ('Initial').

- Stage 2: Risk-Based ('Maturity').

- Stage 3: Deterministic ('Ageing').

• Stage 4: Monitored ('Terminal').

These Stages might be considered as takes after. The four Phases identify with the measure of aggregated harm, the rate of debasement and the edges previously wellness for-benefit is bargained. These may relate to the age of the gear, and it would be typical for hardware to move continuously from Stage 1 to Stage 4 as it gets more seasoned, however this isn't really dependably the case. A few Phases may not matter to a few sorts of hardware, and some of the time gear can be moved back a Phase with suitable support. There are no settled periods or clear boundaries between the Stages. It is matter of judgment from the specific conditions at which Stage the hardware lies and the best administration system.

The time that gear might be thought to be in a specific Stage can fluctuate especially starting with one thing then onto the next relying upon the working condition and life history. The Phase inside the lifecycle can be resolved and controlled from getting some answers concerning the debasement instruments, undertaking evaluation, observing, upkeep, repairs and renovation.

Stage 1: Post Commissioning ('Initial')

As hardware is put into benefit there might be a moderately higher rate of harm collection and issues requiring consideration. There are two primary drivers. The first is the place encountering administration conditions out of the blue uncovers an innate shortcoming or blame in the plan, materials or creation. Commonplace deficiencies incorporate erroneous measurements, flawed material, welding methods and creation deserts that have not been recognized from assembling NDT, or the impact of burdens and situations that were not predicted. Under these conditions, fast corruption of the gear right on time in life is conceivable and it can advance rapidly through the distinctive Stages. Huge numbers of these issues can be wiped out with proper quality affirmation and control. The second reason for early life changes emerges from bedding-in impacts that the gear may understanding as it enters benefit.

These can be because of substantial establishment stresses or harm from mal-taking care of amid establishment. They can likewise be because of varieties in benefit conditions as the hardware encounters 'shake-down' and stacks redistribute themselves all through the structure. Other non-basic manifestations of the 'Underlying' Stage might spill valves, jolts or seals that are not fitted or had relations with impeccably. A large portion of these issues can be overseen through routine support.

Stage 1 trustworthiness issues can be distinguished and tended to at the primary far reaching examination. The planning of the principal examination can be resolved from an exhaustive evaluation of the variables that may undermine trustworthiness ahead of schedule throughout everyday life. These components incorporate the security of all procedure conditions, nature of development and manufacture examination. Where the procedure 46 conditions are steady and a decent unique mark examination (preceding administration) has been made, a hazard appraisal might have the capacity to legitimize a more drawn out period before the main examination than that prescribed in industry direction

Stage 2: Risk-Based (‘Maturity’)

After the hardware has gone through the early-life issues of 'Post Authorizing', it enters the second Stage. The 'Development' Stage is the point at which the gear is unsurprising, solid and is expected to have a low and moderately stable rate of harm collection and few issues requiring consideration. It is working easily inside its outline limits. Examination and assessment, upkeep and NDT are by and large to affirm the reason for these suspicions, and their extension and periodicity can be hazard based.

Stage 3: Deterministic (‘Ageing’)

By this Stage the gear has amassed some harm and the rate of debasement is expanding. Indications of harm and different pointers of maturing are beginning to show up (see Area 3.3). In this Stage it turns out to be more vital to decide quantitatively (consequently 'deterministic') the degree and rate of harm and to make a gauge of remanent life. A more proactive way to deal with gear administration, investigation and NDT is required. Outline edges might be dissolved and the accentuation shifts towards wellness for-benefit and remanent life evaluation of particular harmed zones.

Absence of learning can be the same amount of an issue and can place gear into Stage 3. Learning of the gear's history may have been lost, maybe because of the hardware being second-hand, or changes to the procedure for which the hardware is utilized, or from changes in work force, record keeping and other human variables. It might now never again be conceivable to foresee the present condition or future administration life of the hardware from outline or hazard based contemplations. Second hand hardware is thought to be specifically in Stage 3 unless there are adequate verifiable confirmation and records to show a lower chance.

Stage 4: Monitored (‘Terminal’)

As gathered harm to gear turn out to be progressively serious, it turns out to be evident that the hardware will at last should be repaired, revamped, decommissioned or supplanted. The rate of corruption has turned out to be expanding quickly and isn't anything but difficult to anticipate. In this last 'Terminal' Phase of the hardware's life, the primary accentuation is on ensuring satisfactory security between examinations while keeping the gear in benefit to the extent that this would be possible.

Stage 4 can be overseen through making more utilization of on-line checking of the harmed regions, or by more regular NDT to screen the sizes of defects until the point that they achieve the most extreme decent size, or by repairing unsatisfactory blemishes. A lessening of the seriousness of the obligation, for instance decreasing the weight rating of the gear might be another alternative to augment the handiness before decommissioning. In any case, by Stage 4 no assurances can be made about future administration life past the following examination.

2.2 Damage types and mechanisms

One damage evaluation due to degradation of power plant is dividing them into two categories: there are damages that directly change the material of the equipment and other ones that could prevent the equipment from working properly. The need to introduce difference is born considering the latter and its way not to directly threaten the equipment, as it is, moreover, problems, such as vibration, thermal fatigue or corrosion, can affect the operation of the equipment in a way that eventually becomes a threat to the plant efficiency. Damage to material can be categorised into four main types:

- Wall thinning.
- Physical deformation.
- Metallurgical / environmental damage.
- Stress-driven damage, cracking and fracture.

The relation between the type of damage and the initiating mechanism is deeply related to the equipment and circumstances. It is therefore important to know their direct link, from which derives the difficulty to separate them and describe them in an unique example.

(a) Wall thinning may occur due to:

- *General or localised corrosion or pitting due to corrosion agent*. There are a lot of industrial procedures that require chemical removal of surface material, such as welding processes, so the mechanisms depend on the specific environment and conditions of the plant and its specific productions. The relevance and prediction of a wall thinning due to corrosion, companies have to incorporate a corrosion allowance in the design wall thickness, based on a predicted corrosion evaluation rate.
- *Overgrinding* It could be found as a result of flaw removal. For evaluation, wall thinning is categorised as general thinning, a locally thinned area or pitting.
- *Erosion, erosion-corrosion, scouring*. The action of particles in the fluid that causes the removal material from the surface.
- *Wear, abrasion, fretting*. Determined by the rubbing of two moving parts together.

(b) Physical deformation

- *Dents and gouges*.
- *Buckling*.
- *Yielding*.

(c) Stress driven damage, cracking and fracture includes:

- *Fatigue damage and cracking.* Fatigue is one of the most important causes of damage for most of the plants exhibiting rotating equipment and results from cyclic stresses from varying pressure, or vibration, or resonance of small cracks generated within the structure and often also not visible by human beings, or thermal expansion/shocks. Corrosive conditions could increase the rate of cracking.
- *Creep cavitation and creep crack growth* caused by high temperature stresses.
- *Stress corrosion cracking (SCC*) occurs in a specific environment requiring a susceptible material at the presence of an evident stress phenomenous. It introduces a quick split proliferation rate, and an extended sort break morphology, which can be intergranular or transgranular. SCC in various structures. Situations that may cause SCC are particular to the material.
- *Stress impacted hydrogen* splitting hydrogen is available in a material affected by a connected malleable pressure or remaining pressure. This, in conjunction with the low malleability, can prompt crack. Illustrations incorporate creation hydrogen splitting and stretch arranged hydrogen actuated breaking (SOHIC).
- *Brittle crack or cleavage*. Ferritic materials worked at low temperatures might be especially helpless unless materials met all requirements for low temperatures are utilized.
- *Ductile tearing* of prior imperfections which would then be able to bring about crack.

(d) Metallurgical and natural harm (beside SCC) includes a change to the metallurgy and properties of the material. It covers:

- Hydrogen embrittlement. Loss of pliability in steels and some different composites because of the nearness of nuclear hydrogen, frequently because of hydrogen being consumed by the metal from a reasonable situation. This can cause pressure consumption breaking, disbanding of clad erosion safe composite layers, and manufacture hydrogen splits.

- Temper embrittlement of low combination steels is caused by holding inside, or cooling gradually through temperatures just underneath the change go, commonly in the scope of 450-475o C.

- Strain age embrittlement of ferritic steels. Loss of pliability (and ascend in quality) caused when a low carbon steel is metallurgically matured under maintained pressure, time and temperature following plastic misshaping (e.g. an imprint). The level of embrittlement additionally relies upon the grouping of components, for example, carbon and nitrogen in the steel.

- Embrittlement from different sources, for example, sigma stage development in some stainless steels. • Blistering/Hydrogen (Pressure) Induced Cracking (HIC/HPIC) Dissolved nuclear hydrogen in the steel recombines at incorporations and results in surface rankling or inward splitting.

- Hydrogen assault. The response of disintegrated hydrogen with carbides in ferritic steels bringing about decarburization and porosity. Can be stayed away from through right steel determination.

- Type IV splitting is high temperature crawl breaking that happens over long circumstances at areas of high pressure, e.g. the external edge of the unmistakable warmth influenced zone (HAZ) in ferritic steel weldments or territories of neighborhood twisting. It has been distinguished in most crawl safe low combination ferritic steels, e.g. 1-1.25%CrMo, 2.25%CrMo, 9%CrMoVNb. 50

- Reheat breaking for the most part happens in the weld combination line in steels alloyed with mixes of Cr, Mo, V and B. In the welding procedure amid warming of the HAZ (e.g. for the most part amid post weld warm treatment or consequent welding), splits frame along debilitated grain limits.

- Flame impingement can change the metallurgical microstructure of a material similarly as warmth treatment.

- Ageing of polymers because of introduction to bright radiation, high temperature or compound assault

2.3 The cost of Cycling Power Plant

Cycling alludes to the activity of electric producing units at different load levels, including on/off, stack following, and least load task, because of changes in framework stack necessities. Each time a power plant is killed and on, the evaporator, steam lines, turbine, and helper segments experience unavoidably vast warm and weight stresses, which cause harm. This harm is exacerbated for high temperature segments by the marvel we call crawl weariness collaboration. While cycling related increments in disappointment rates may not be noted instantly, basic segments will in the end begin to come up short. Shorter segment futures will bring about higher plant comparable constrained blackout rates (EFOR) or potentially higher capital and support expenses to supplant segments at or close to the finish of their administration lives. What's more, it might bring about decreased general vegetation. How soon these hindering impacts will happen will rely upon the measure of crawl harm display and the particular sorts and recurrence of the cycling.

In any case, cycling a unit represents a multi-dimensional issue that is hard to understand or fetched assess. The test extends continuously on the grounds that "cycling task" is a wide idea that envelops stack following, low load, hot begins, warm begins, and cool beginning of a plant with various time allotments between activities; it is unquestionably not exclusively time-based. Is it all the more fiscally reasonable to close down a specific unit during the evening to spare fuel and acquire the large number of cycling expenses or remain online at least load and consume fuel? The response to that inquiry is clearly unit/framework particular, yet there are a few patterns in view of customer encounter after the genuine cost of cycling has been resolved. On account of a few investigations we can watch that numerous organizations have diminished unit least loads from 5% to 20% of evaluated stack on fossil boilers so units can "stew" overnight. This approach keeps the gear hot and prepared to rapidly increase to full load (a major preferred standpoint in a focused market), yet it utilizes least fuel during the evening.

Around 60% to 80% of all power plant disappointments are identified with cycling tasks. A study of 215 steam plants discovered numerous normal hardware issues: the most continuous is warm pressure, trailed by erosion and water acceptance, different issues are pivotal relocation, vibration wear, outward pressure and quick cooldown, as can be appeared by the chart. (Hesler, 2011)

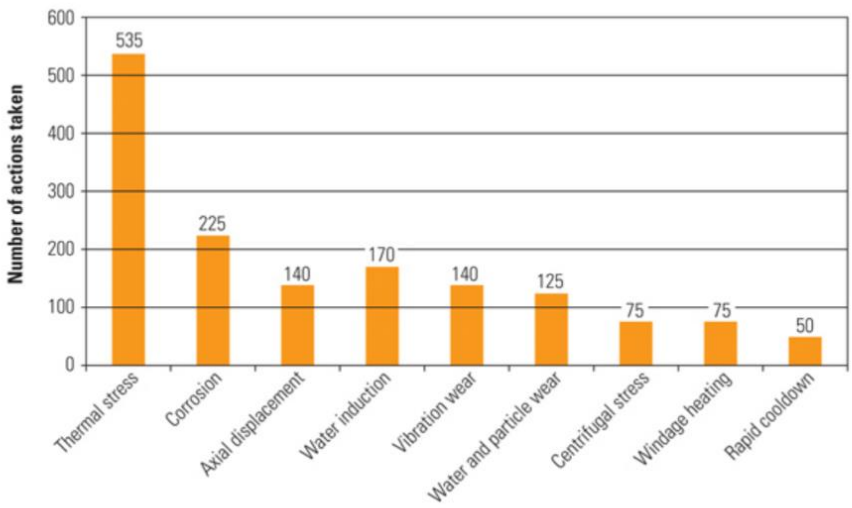


Figure 8 - Common problems in cycling plants

Failures in coal plant equipment caused by visit cycling are not segregated occasions but rather regularly happen at surprising circumstances all through a plant. A significant number of the disappointment modes and areas are not sudden, but rather others might shock even to an accomplished plant administrator. Counteractive action of these disappointments or overseeing disappointment rates is critical to progress. One way to deal with lessening cycling harm is to alter the unit's low-stack breaking point to avert cycling harm. By decreasing the low-stack confine on a 750-MW supercritical gas-let go unit from 150 MW to 28 MW during the evening, it was conceivable to make the day by day cycling load gainful, yet it was no little errand. The accompanying subsections are given to give you a feeling of the greatness of frameworks and segments inside a run of the mill coal-terminated plant intended for baseload task that are influenced by cycling and load-following administration. Despite the fact that they are not recorded independently, controls are additionally influenced; a few plants must redesign old simple controls to computerized controls with a specific end goal to enhance reaction to remotely provided programmed age controls before they are equipped for cycling.

Steam Turbine Generators

The life of a steam turbine is specifically identified with warm drifters experienced after some time. Truth be told, the run of the mill steam turbine startup incline rate is all around characterized by the producer, as there are points of confinement to the warming rates of the turning parts. Steam turbines require ease back temperature changes to deal with the warm worry in their overwhelming metal parts A fundamental outline component of a solid cycling unit is a steam sidestep framework. At the point when in activity, high-temperature steam is weight decreased and cooled by blending condensate with the hot steam in a superheater and afterward skirted around the steam turbine to the condenser. Extra steam sidestep to the condenser frequently requires condenser changes. In some steam turbine outlines, the steam seals may should be supplanted to keep steam spill out of bypassing the rotor stages or areas. At last, an electric warmed turbine cover framework might be useful amid hot restarts to decrease warm pressure and contortion, guaranteeing a speedier begin.

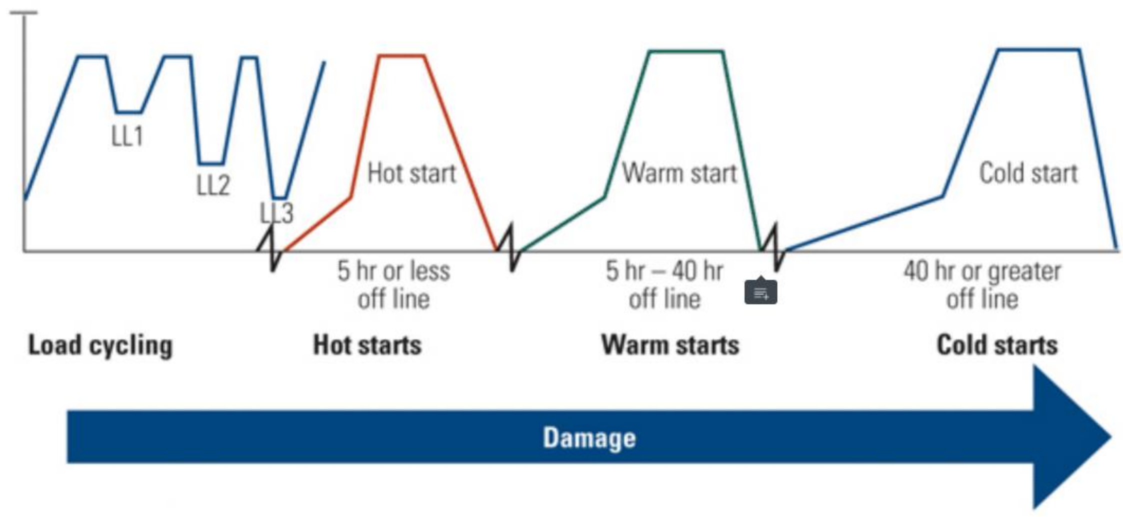


Figure 9 - Relative damage caused by cycling steam plants

Boilers

In the superheater area, harm to tubing is typically caused by overheating that outcomes from low or no stream of cooling steam through the tubes amid startup or potentially poor burning gas temperature administration. Harm to superheater tubing is normally obvious by extreme bowing and warm contortion because of overheating harm of tubes completely uncovered in the gas way.

Likewise, superheater tube harm can come about because of condensate, and stagnate or turn around steam streams amid startup. Comparable overheating harm regularly happens in reheater tubing.

Figure 10 - Breaking Bad

Consumption exhaustion harm in the steam-cooled divider in the warmth recuperation territory is apparent in the accompanying photograph. The steam-cooled sidewall has a harmed economizer header infiltration. Cycling caused differential warm development, and the infiltration is severely harmed.

The impacts of cycling the steam generator normally appear as pressure splitting in the waterwall tubing at connections like the windbox, corner tubes, and divider box openings. Stress breaking in the waterwall tubing at the buckstay connections is normally caused by nonuniform warm development of the evaporator and its emotionally supportive network.

Despite the fact that temperature levels are much lower in the economizer, warm harm can even now happen there. Economizer tube disappointments are generally caused by warm stunning of the bay header and tubing with moderately chilly water, frequently amid startup. Consumption may likewise happen in regions of the economizer where chilly water decreases the metal temperature (structure or tubing) underneath the corrosive dew purpose of the stack gas amid low-stack activity. At the point when the stack gas is lessened beneath the corrosive dew point, the moment parts of sulfur that stay in the gas can join with the consolidated dampness and frame weaken arrangements of exceptionally destructive sulfuric corrosive on tubes and structures. In expansion to evaporator plan and activity caused tube disappointments, poor heater water science control can be a contributing reason. In a few plants, the whole water science program must be reformulated to upgrade remaining heater tube life. Often, the way to diminishing waterwall tube wastage is essentially utilizing a nitrogen cover over the inner tube wetted surfaces when the kettle is expelled from benefit or depleting it. Additionally, consider a nitrogen cover in the condensate stockpiling tank to limit the oxygen content in the condensate amid begins. In warm recuperation steam generators (HRSGs), the average cycling issues can be followed back to superheater and reheater channels that neglect to clear aggregated condensate. Stream quickened consumption (FAC) in the low-weight evaporator and disappointment of feedwater warmers from warm stun and FAC likewise are frequently found.

Fuel Systems

Coal pulverizers are inclined to fireside blasts, particularly when utilizing western coals. They require cautious fuel cleansing and the expansion of an idle gas cover (inerting) when they are cycled disconnected. Likewise, pulverizers are inclined to much expanded mechanical wear when they are cycled or worked at the low end of their plan least stream rates.

Another unforeseen outcome of cycling a strong fuel plant is the extra support required on the coal storehouses. At the point when consume rates are hard to anticipate, the holding time of western coals in storehouses can reach out past six or seven days, the greatest time thought about safe. Longer stockpiling of western coals regularly causes an expansion in the recurrence of problem areas and flames inside the coal storehouses. A similar security issues apply to coal heap administration and stock control, as consume rates continually change because of plant stack cycling or low-stack following.

Air and Gas Turbines

The constrained and actuated draft fans on coal-terminated units can go from a couple of hundred to well finished a thousand drive. Visit beginning and ceasing of the fans—and, similarly as essentially, the engines that drive the fans—will build disappointment rates, examination interims, and engine fan upkeep. Now and again, fans have required retrofit of new drive frameworks for delicate or low-stretch beginning. Moreover, air warmers and baghouses are liable to wet gas consumption, stopping, and harm caused by working underneath the wet gas dew point amid low-stack activities.

Water Systems

It might appear to be outlandish, yet cosmetics water utilization enormously increments for a cycling unit as a result of the a lot of water utilized amid startup. Indeed, it's conceivable that the plant's demineralized water supply and water stockpiling may need to increment to help the expanded heater water use. The whole feedwater framework is influenced by thermally cycling plants. For instance, feedwater radiators are liable to cooldown and fast warming amid a hot or warm startup cycle, and this regularly prompts early tube disappointments. Heater encourage pumps are typically intended for full-stack task and experience quickened wear when worked at low loads. Additionally, evaporator encourage pumps might be required to stop and begin a few times for one startup cycle, in this manner causing numerous feedwater homeless people. In a few plants, a littler, low-stack feedwater pump might be essential for a cycling unit to restrain harm to the principle feedwater pumps. In others, kettle feedwater and condensate pumps may require included distribution capacity, and the economizer may expect distribution to hold leave water temperatures under wraps.

Combustion Turbines

Gas-let go consolidated cycles might be speedy acting in correlation with a coal-let go plant, yet they are not resistant to a similar warm stress– related hardware harm depicted previously. In view of our involvement with joined cycle plants, we have discovered that the biggest detail on a plant's working and upkeep spending plan is costs identified with cycling.

One reason cycling costs are relatively higher in joined cycles is that turbine assessment and repair interims are progressed to being chiefly in light of quantities of begins as opposed to working hours. Subsequently, the cost to keep up joined cycle accessibility is high on a for every unit-of-power created premise. The cost of new parts discovered harmed amid updates, or "parts aftermath" because of cycling, is frequently a factor of at least two over the vegetation contrasted and baseload activity.

2.4 Common failures in Power supply and distribution

This session evaluates the common risks in coal fire plants. First of all, it is helpful to determine the distributions of losses. Thanks to some literature researches, we could understand how common are the failures or the accidents in the coal-fired power plants. This study, using an original historical dataset over the period 1874-2014, evaluates that risk across 11 energy systems.

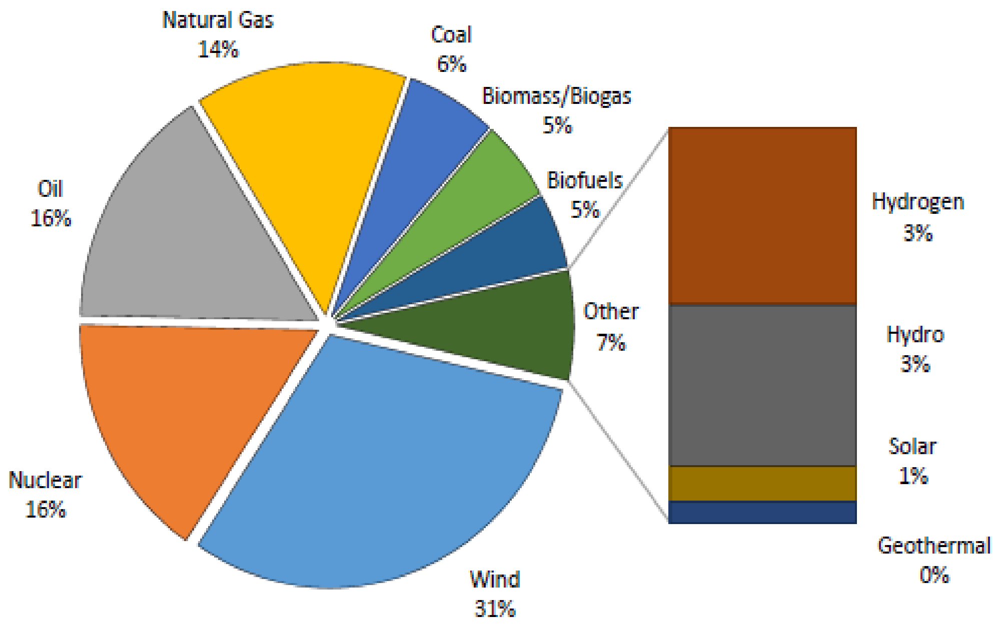
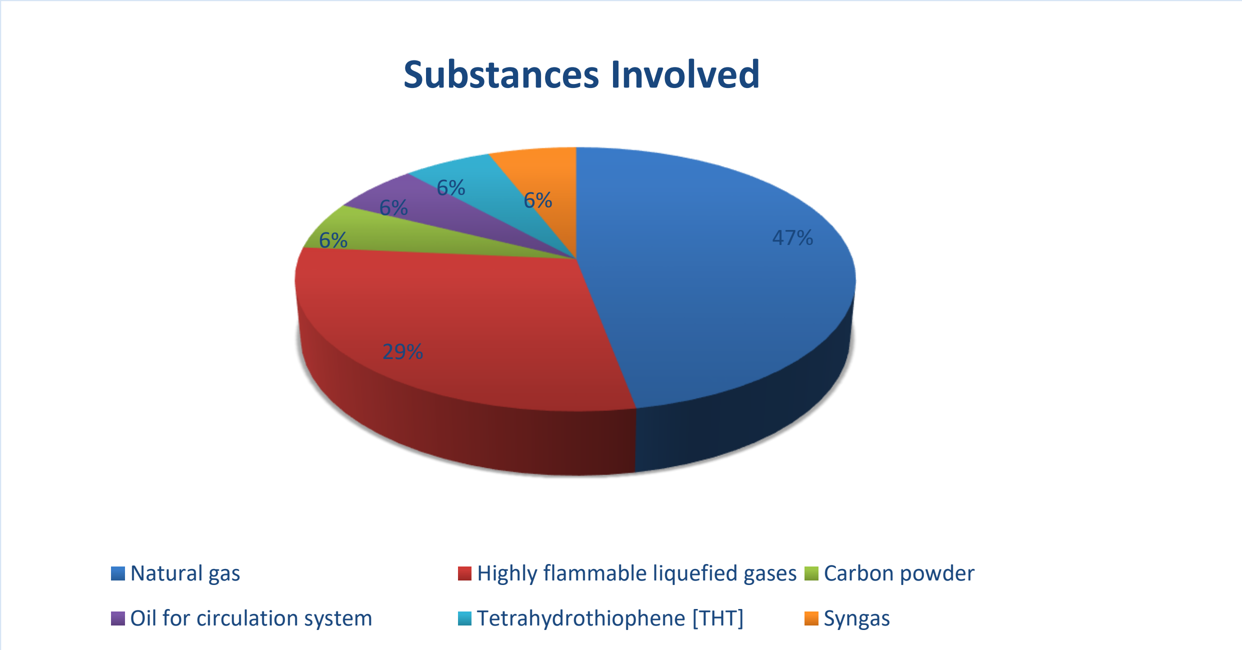


Figure 11 - Accidents occurred over the period 1874-2014

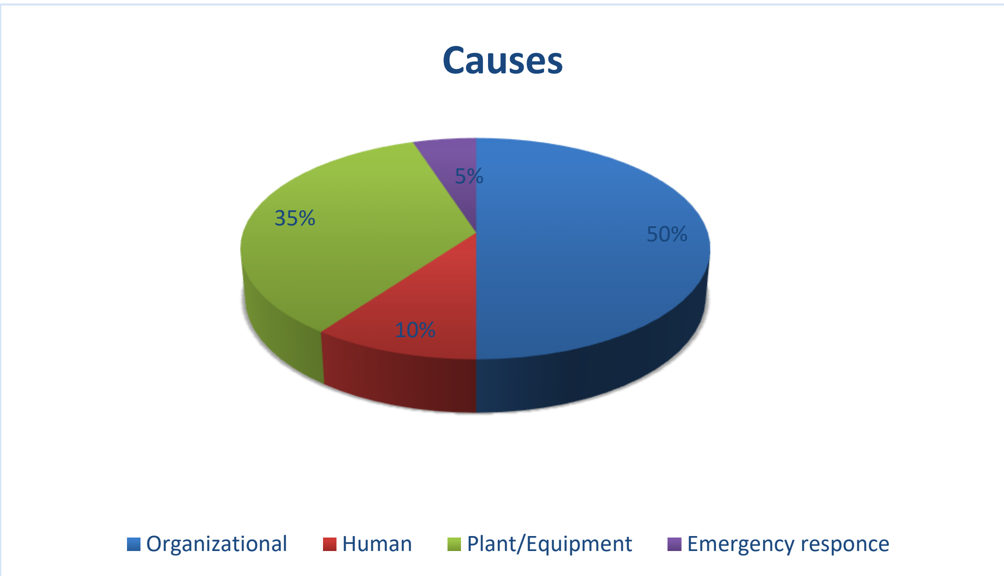
As this Fig indicates, wind energy (31 percent) and nuclear power (26 percent) accounted for more than half of all accidents by frequency, and the combined fossil fuels (coal, oil, and natural gas) accounted for only 36 percent, in which coal is just 6%. One obvious explanation here is lack of pubic data and it is very likely that many accidents in the fossil fuel chain are either not reported, underreported, or are reported in languages other than English.

In order to support these studies, it was necessary to use an online datasheet in which it is possible to find some of the information released by the Seveso Legislation. eMars is a Major Accident Reporting System.

We considered all the Power supply and distribution issues happened between 1990 and 2012, which has reported 17 failures.



As is shown from this pie chart, the first thing to focus on is what are the substances involved in those accidents: the most common is the natural gas, followed by the flammable or highly flammable liquefied gases. We cannot find a specific coal characterization, but we can collocate it in the fossil fuel group, such as natural gas. Subsequently we evaluated from all of these injuries the *release major occurrences*, most of them are not identified (45%), but the 44% consist in a gas release to air, that is so difficult to manage. Then we classified the part of the plant that is involved: the 74% is equally divided into power plant, such as a heat generating area, and pipeline. The remaining part is divided into gas holders and turbine. Before focusing on the causes of accidents, it's better to consider what are the main reasons regarding the study of the events considered: 53% is related to the characteristic of the substances, followed by the injuries to persons 21%, and by the damage to property 16%. The last 10% it refers to interesting cases for lessons learned.



Finally, we evaluated the causes of accidents: half of those are caused by organizational mistakes, this means that 50% of accidents can be avoided by implementing a program that can handle an innumerable amount of news, so we need to develop a robust safety indicator tracking program that uses the data identified to drive continual safety improvement. The 35% consist in Plant/Equipment causes, or in the characteristics that it presents the equipment, human causes occurring in 10% of cases, and finally, the remaining 5% is due to emergency response.

It is clear that evaluate these incidents is crucial to understand what are the problem that mostly occurs in plants, and above all we must understand what are the causes that determine them: so we need first to focus on the major sites described on eMars studies, and what could happen over there, which are the causes that determined that accidents; and then we must understand the need to use programs that perform day by day analysis, that can handle and share a large number of real-time information, and that can prevent collateral damage.

Thanks to the literature review, we could have focused on three principals, major accidents in this kind of plant: first of all the steam. The article *"Safety Issues in Fossil Utility and Industrial Steam Systems" (Otakar Jonas, Ph.D., P.E.)* shows the incidents occurred in 2001. 49% of the total boiler issues is caused by the heating ones that use steam, followed by the same ones that use water, even though the highest number of fatalities occurs in power boilers.

Component[1]	Damage Mechanism[2]	Major Influences[3]	Destructive Failures[4]	$ Impact[5]
Steam Piping [6 to 8]	Creep	Welds, temperature, time	Yes	10^7
	LCF, LCCF	Temperature changes		
	Carbon steel graphitization	Temperature and time	Yes	
Drums and Headers [6 to 8]	LCF, LCCF, SCC	Temperature cycling, design, water chemistry	No	10^7
Boiler Tubes [10]	LCCF (20 others)	Water chemistry, cycling, heat flux, etc.	Yes	10^6
Feedwater and Wet Steam Piping [9, 14 to 16]	FAC	Design, water chemistry	Yes	10^7
	Cavitation	Design, operation	Yes	
	SCC	Residual stress, chemistry	No	
	CF, LCCF	Weld quality, water chemistry, temperature changes	No	
Deaerator, Flash Tank, Hot Water and Steam Vessels – Welds [9, 17]	CF, SCC, FAC	Design (water piston), residual welding stress, operation, water chemistry	Yes	10^7
LP Turbine Rotors and Disks [9, 11 to 13)	SCC	Design stresses, temperature", high strength steel, steam chemistry	Yes	10^7
	CF	Steam chemistry, design, vibration	No	
LP Turbine Blades [9, 11 to 13)	CF SCC	Steam chemistry, design vibration, pitting, erosion, High strength steel	No	10^6
HP/IP Turbine Rotors [8, 11 to 13]	LCF	Cycling, inclusions, fatigue design	Yes	10^7
Turbine [11 to 13]	Destructive Overspeed	Steam chemistry (boiler carry-over) - sticking valves	Yes	10^7 - 10^8
Turbine [11 to 13]	Rubbing	Steam chemistry, deposits, thrust bearing, expansion	Yes	10^7

1. Numbers in [ ] are References
2. CF - Corrosion Fatigue, LCF - Low Cycle Fatigue, LCCF - Low Cycle Corrosion Fatigue, SCC - Stress Corrosion Cracking, FAC - Flow-Accelerated Corrosion
3. Age influences the degree of damage for all issues except the last two
4. At least one destructive failure during the last 30 years
5. Lost production and repairs per one event. The cost of lost production is typically much higher than the loss from repairs with a ratio up to 10:1.

Table 12 - Major damages

As this table shows, generally the corrosion is the most important problem that you can find when steam is produced, the damage mechanisms are: corrosion fatigue, low cycle corrosion fatigue or stress corrosion fatigue. The major equipment's influences are: the temperature, the design of the component, or the steam chemistry, that it depends on where the steam comes. If we focus on the causes that determine those accidents in power boilers we can see that the most numerous accidents were reported due to low-water condition, followed by the operator errors or poor maintenance which causes the most numerous injuries and fatalities. 10% consist in burner failures.

We have found an article in which root-cause analysis of a burner tip failure was investigated employing stress modeling in the burner tip material, using the Computational Fluid Dynamics (CFD) software FLUENT.

If we focus on faults caused by maintenance activities, thanks to the paper "*An analysis of maintenance failures at a nuclear power plant" Pekka Pyy,* we can show that the main causes of failures occur in the control and instrumentation equipment, in greater quantities only for lack of attention or because the object is wrong! This emphasizes the need for a program aimed at managing data in an efficient and controlled way.

To give a real insight to this investigation is necessary also to examine Chemical Safety Board articles. The CSB is an independent federal agency charged with investigating industrial chemical accidents. It conducts root cause investigations of chemical accidents at fixed industrial facilities. Root causes are usually deficiencies in safety management systems, but can be any factor that would have prevented the accident if that factor had not occurred. Other accident causes often involve equipment failures, human errors, unforeseen chemical reactions or other hazards. The agency does not issue fines or citations, but does make recommendations to plants, regulatory agencies such as the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA), industry organizations, and labor groups.

It was taken the example of an explosion of a heat exchanger, or better than a reboiler of a distillation column, in which the safety valves were located upstream of the entire apparatus, too far to the heat exchanger. The incident occurred during non-routine operational activities that introduced heat to the reboiler, which was offline and isolated from its pressure relief device. The heat increased the temperature of a liquid propane mixture confined within the reboiler, resulting in a dramatic pressure rise within the vessel. The reboiler shell catastrophically ruptured, causing a boiling liquid expanding vapor explosion (BLEVE) and fire, which killed two workers; 167 others reported injuries, the majority of which were contractors.

Another CSB investigation regard the ammonia release, a problem that we can found in this coat power plant; the ammonia is injected into the flue gas stream, in the selective catalytic reducer

(SCR), where reacts with several catalysts layer to reduce the NOx compounds. The investigation was about a plant a bit different, anyway in the event of an ammonia release that cannot be promptly isolated, CSB investigation suggest activating the emergency shut-down switch to de-energize pumps, compressors and valves instead of attempting to isolate leaking equipment while the refrigeration system is running. Shutting down the equipment will stop the circulation of ammonia and limit the release of additional ammonia from components running upstream of failed equipment or piping.

We have to underline that most of these plants use distributed control systems (DCS) to simultaneously control thousands of process variables such ad temperature and pressure, level of the liquid, composition. The major human role in this control is to supervise these highly automated systems. This supervisory activity requires: monitoring plant status, adjusting control parameters, executing pre-planned operations activities and detecting, diagnosing, compensating and correcting for abnormal situations.

Based on those experience with root cause and failure analysis, the following weaknesses in the industry's handling of the safety issues can be identified:

- Lack of knowledge and/or its application by designers, operators, and inspectors; particularly in industrial steam systems.
- Only artificial determination of the root causes. An estimated 40% of the root causes are not correctly determined.
- Missing material data, particularly on creep - fatigue and fatigue - corrosion interactions.

The conclusion is that a combined cycle power plant alarm system developed by the plant designer can provide very high-quality results and long-term operating and maintenance advantages as it benefits from the engineering knowledge.

We need to conduct safety culture assessments that involve workface participation, and communicate the results in reports that recommend specific action to address safety culture weaknesses; we need to develop a robust safety indicator tracking program that uses the data identified to drive continual safety improvement; moreover, we need to perform comprehensive process safety program assessments to thoroughly evaluate the effectiveness of the facility's process safety programs.

3. Asset management standards and aging equipment: risk based decision making and operational risk monitoring

Compelling control and administration of advantages by associations is basic to acknowledge an incentive through overseeing danger and opportunity, with a specific end goal to accomplish the coveted adjust of cost, hazard and execution. The administrative and authoritative condition in which associations work is progressively testing and the innate dangers that numerous benefits introduce are continually advancing.

The essentials of advantage administration and the supporting resource administration framework presented in this Universal Standard, when coordinated into the more extensive administration and hazard structure of an association, can contribute unmistakable advantages and use openings.

Resource administration makes an interpretation of the association's goals into resource related choices, plans and exercises, utilizing a hazard based approach. Resource administration empowers an association to acknowledge an incentive from resources in the accomplishment of its hierarchical destinations. What constitutes esteem will rely upon these targets, the nature and motivation behind the association and the requirements and desires of its partners. Resource administration bolsters the acknowledgment of significant worthwhile adjusting money related, natural and social costs, hazard, nature of administration and execution identified with resources.

In complex establishments, it is suitable to have a characterized composed strategy for administration of the advantages regarding the gear, and the sustain and item stock. This may give recognizable proof of the dangers from disappointments (both hardware and human), and an appraisal of gear condition and wellness for-benefit. The advantage administration strategy will be particular to the kind of industry, plant area, and destinations.

The approach record may characterize (yet not list, aside from maybe in Supplements) the advantages worried, with a diagram of a methods for overseeing, reviewing and keeping up each kind of benefit, and the outline life of each plant or resource. As a nonexclusive report, it will bargain practically with hazard (to security, business, notoriety, work, and neighbors), perceiving that all exercises convey some hazard and that the goal is to oversee hazard to the advantage of all. It might characterize the structure for plant blackouts and unwavering quality focuses as far as generation or accessibility.

3.1 Structural Integrity Management Plan

The Benefit Administration Approach Archive may reference a Basic Trustworthiness Administration Design (SIM Plan). This is an especially critical report for establishments where there are high perils as well as the stock of hardware is expansive. The SIM Plan will typically set out the methods and systems by which basic respectability is guaranteed to meet statutory and companies' prerequisites. Run of the mill components referenced in a Basic Uprightness Administration Design, called a Structural Integrity Management Plan include:

- The original design assessment and design life
- Operating limits and instructions
- Maintenance policy document and equipment schedules
- Inspection policy and schemes of examination
- Fitness-for-service assessment and revalidation
- Repairs, modifications and replacements procedures
- On-line and periodic condition monitoring
- Equipment retirement policy

The arrangement ought to consider collaborations between these components and the relative quality and mix of the components required for various classes of hardware.

3.1.1 Maintenance Policy

It is great practice to have a record that depicts the upkeep strategy for gear. Producers' proposals for upkeep might be sound yet can be over-defensive. A hazard based approach is to distinguish the wellbeing and creation basic gear, and to break down what may turn out badly and set support arrangement appropriately. Elective methodologies can be condition-based or unwavering quality focused.

Common results can run from 'no upkeep' through expanding levels of observing, examination and support. The subsequent support plan is a harmony between the effect of doing upkeep (cost, exertion, downtime, danger of harm), and the effect of a disappointment (wellbeing, cost, downtime). At the point when the upkeep strategy and calendars have been characterized, they ought to be disclosed to those engaged with their execution. It is valuable to have a component for criticism on execution through a framework for recording and dissecting gear disappointments. This would then be able to frame the premise of an enhanced arrangement to adjust upkeep cost and contact with the money related outcomes of potential disappointments.

3.1.2 Examination, Inspection and NDT Policy

Examination, investigation and NDT are frequently an imperative piece of overseeing gear by giving data on the condition important to affirm that it stays inside plan confines or to survey wellness for-benefit. Pointless review can be adverse on the off chance that it includes opening or irritating gear, or permitting in destructive media. It can expand the danger of future disappointments (e.g. by harming slacking, defensive coatings and flanged joints). Off base utilization of NDT or improper determination of assessment zones can deliver an incorrect feeling that all is well with the world by announcing no harm in the zones reviewed, while harm may have happened, or harm somewhere else might be missed. Assessment influences creation and is normally work serious, and can hence be a critical cost.

Thus, review of gear ought to dependably be very much established, and ought to be intended to look specifically areas for particular conditions, estimations, deformities and blemishes. Hazard based review (RBI), potentially in view of a disappointment mode and impacts investigation (FMEA), or if nothing else authority learning and experience, can be a decent and perceived approach. Where the data required to help chance based assessment isn't accessible, and for certain high peril low likelihood of disappointment hardware, a broader investigation might be utilized to build up or affirm changes to the gauge condition.

Plans of examination should adjust to the age and state of gear and to the learning of its disintegration. For weights frameworks more than 250 bar-liters, PSSR 2000 requires the utilization of an Equipped Individual to draw up or potentially guarantee as reasonable a composed plan of examination. By and large, the assessment strategy needs to distinguish the way to deal with review arranging and execution, and the arrangement of NDT administrations.

New hardware, especially on new procedures or with new materials, may have no known history (e.g. of consumption rate) and may require more regular investigation. Ahead of schedule in life there might be extraordinary incentive in a succession of estimations (e.g. thickness) assumed at a similar position, joined with a visual investigation investigating regions, which may be hard to get to or to clean. On hardware where encounter indicates little consumption more than 90% of the zone, there is little point in proceeding with nitty gritty thickness checks over the entire surface once this is set up.

Most assessment strategies will incorporate visual examination of interior and additionally outside surfaces. It is proper to utilize NDT to supplement visual examination for the discovery of blemishes that might be imperceptible to the exposed eye. NDT can affirm and evaluate expected decay components, and, when utilized at a suitable interim, gives a way to condition checking.

Keeping in mind the end goal to give a measure of safeguard top to bottom, the examination and NDT approach may need to incorporate components that would perceive harm because of unexpected instruments, i.e. theoretical assessments. Notwithstanding when a full RBI has been produced with sound information of the procedure task, constrained theoretical investigation might be utilized to affirm its suspicions.

3.1.3 Strategies for Managing Corrosion and Vibration

In numerous plants, erosion and vibration are dangers to uprightness that are so all around perceived that it bodes well to have particular techniques for overseeing them.

Repair and substitution of eroded parts can be a huge cost to all plants. The administration of consumption is a complex yet achievable goal, however which can deliver investment funds over the long haul. The subtle elements of the strategies are outside the extent of this report, and include understanding the materials included, condition (inside and outside) as identified with criticality of the procedure and the hardware. At its least complex level a consumption procedure might be only a calendar for repainting; at its most complex it might include the advancement of process conditions and all-encompassing plant financial matters. Master consumption or materials engineers have helped numerous organizations draw up a system, diminish repair and upkeep costs, and show consistence with authoritative necessities.

Vibration has comparative issues, however is as a rule (yet not only) related with turning hardware and high streams. It can ordinarily be overseen by utilization of various strategies. Drawing up a proper technique to oversee vibration has an indistinguishable prerequisite from erosion for fitting master support to give financially savvy guidance. The advantages from diminished vibration incorporate lessened power utilization, wear, commotion, danger of splitting, administrator weakness and gear disappointment rates.

The vibration relief technique can incorporate the evaluation of areas at vibration chance (e.g. little bore associations), strain measure observing, re-adjusting of pivoting hardware, enhanced backings and pipe-course upgrade. Filthy or scaling obligation, develop of stores, (which cause outof-adjust and wear, regularly of course), and quick changes in stack and additionally the working condition (e.g. wind) are normal reasons for disappointment. It might be worth observing vibration intermittently, which is regularly done as a visit by an authority or prepared administrator, utilizing a hand-held screen with an information lumberjack. The outcomes are then stacked onto a PC, slanted, and nonconforming things distinguished.

Ceaseless vibration checking can be utilized as a procedure device (e.g. to recognize fouling on a rotator). At the point when vibration levels rise gradually finished a drawn out stretch of time, it is exceptionally hard to characterize the time when gear is unquestionably harmed and ought to be halted. Ready levels (e.g. process wash, ready administration, stop and detach) ought to be characterized by administration and set into the instrumentation or observing ready gear. Vibration identified on hardware that does not typically vibrate (e.g. warm exchangers) is regularly an indication of issues and ought to be examined instantly. Also, a total absence of vibration on something that typically vibrates shows a disappointment, yet presumably does not demonstrate a security issue, unless it concerns disappointment of segments, for example, a stirrer or instigator in a bunch reactor. The methodology ought to recognize and prescribe activity for these possibilities.

3.1.4 Strategies for Machinery

Control of the unfriendly impacts of maturing of machines is an essential component in honesty administration, yet there are different perspectives that are similarly vital. In the first place you have to guarantee that the gear is reasonable for the reason for which it is given. This evaluation is by and large more unpredictable for machines than for static hardware: machines by and large have less resilience to use in circumstances to which they are not suited.

A similar fundamental harm system apply to machines as to static gear, at the same time, as a rule, machines bomb all the more as often as possible. The honesty of machines ought to be made do with a more noteworthy accentuation on the utilization of fitting support that sufficiently controls the danger of loss of regulation. Average upkeep exercises may incorporate destroying for assessment, substitution of worn or harmed or life-lapsed parts, modification and oil.

Every support action ought to be arranged ahead of time to guarantee that the required time and assets are accessible. On obligations with dangerous liquids, support recurrence is typically time-based or condition-based. Some gear might be keep running with no booked upkeep (e.g. pumps) based on a hazard appraisal. Possibly dangerous breaks from seals ought to be overseen by reasonable wellbeing basic control alerts, or low peril releases spotted amid routine investigation.

Time-based support is suitable if the rate of crumbling is both known and reliable. Time in this setting can either be date-book time or time to achieve a characterized position, for example, working hours or aggregate throughput.

On-line condition checking can either be consistent or occasional. Both are completed with the hardware in activity. The previous gives a constant perspective of the deliberate parameters, however it is costlier to introduce and work. The last gives irregular data and thusly has more shot of missing quick crumbling. In any case, when all is said in done, crumbling because of ordinary maturing components is moderately moderate, and occasional condition observing is reasonable giving that the interims are not unnecessary.

The condition observing systems that are most usually utilized for machines are vibration and oil testing. Thickness testing and thermography are additionally helpful apparatuses. Execution measures, for example, stream, weight, temperature and power draw are the best methods for distinguishing fouling or blockages.

3.1.5 Process Control

Debasement of gear is typically unequivocally connected to the procedure working conditions regarding the earth, burdens and obligation. Process control is hence a critical piece of the gear administration system. Its points are to guarantee that hardware works inside its safe working cutoff points, while upgrading execution and limiting corruption, and it is a key instrument to dragging out gear life.

Process conditions are frequently changed over the life of a plant, possibly because of changes in item, process or limit. There may likewise be changes in conditions on occasion of shutdown, start-up, cleaning/sterilization. It is imperative to perceive and survey the effect of such changes, and great co-activity between administrators, upkeep and materials engineers is a noteworthy piece of process control.

By and large amid wellness for-benefit evaluation where harm has been identified, it has turned out to be evident that adjustments in activity expanded corruption rates or presented components that were not considered at outline. Little changes that might not have been huge, as individual advances (e.g. little temperature changes, altered flush frameworks) ended up essential over expanded activity. It is regularly hard to anticipate the effect of process change over a broadened period, and where there is question expanded observing or potentially review is suitable.

3.1.6 Role of Insurance

As a component of their business resource administration technique, associations will frequently secure their advantages and liabilities through the use of protection. Commonly, a building protection bundle for a bit of mechanical hardware would incorporate such cover characterized misfortunes because of 'Sudden and Unexpected Harm' which would incorporate breakdown, blast and fall of the safeguarded property. These terms are typically characterized as takes after:

- Breakdown is characterized as "the genuine breaking, bending or wearing out of any piece of the guaranteed property, while being used, emerging from mechanical or electrical deformities causing sudden stoppage which requires repair or substitution before it can continue typical working"
- Explosion is characterized as "the sudden and brutal rendering of the weight plant, by power of inward liquid weight causing substantial relocation of any piece of the weight plant together with persuasive launch of the substance"
- Collapse is characterized as "the sudden and unsafe contortion of any piece of the weight plant caused by pounding worry by power of steam or other liquid weight"

For any harm to gear safeguarded along these lines, the sum payable is ordinarily computed based on reestablishment of the guaranteed property or other property obliterated or harmed. Reestablishment is characterized in two ways:

- Where the guaranteed property is devastated "its substitution by comparable plant of a condition equivalent to, yet not superior to, its condition when new"
- Where the guaranteed property is harmed "the repair of the harmed segment to a condition considerably the same as, however worse or more broad, than its condition when new"

A run of the mill protection arrangement of this write would not ordinarily cover:

- The concurred abundance sums
- Loss or harm by flame or robbery and so forth
- The cost of support or correction of flawed workmanship
- The cost of correction of:

a) wear and tear, disintegration, consumption or other crumbling caused by, or normally coming about from, standard work uses or presentation

b) step by step creating imperfections or breaks which don't require prompt stoppage

- Consequential misfortunes
- Psychological effect of a vessel disappointment on the two representatives and clients and the loss of partner certainty.

Protection strategies don't by and large cover the repair and amendment of harm because of dynamic disintegration. Where harm prompts sudden breakdown, for example, a release or more cataclysmic disappointment, the protection repayment may rely upon whether the harm was sudden and unanticipated, or normally coming about because of customary work utilize, and the manner by which the hardware was being overseen.

It is a typical state of protection arrangements that the guaranteed should play it safe to shield the safeguarded property against misfortune or harm. They might keep up it in a proficient condition and find a way to guarantee that all Legislature and different controls identifying with the activity and utilization of the safeguarded property are watched. Under these conditions, most maturing instruments emerging normally from customary work utilize and presentation ought to be predictable; the courts are probably not going to acknowledge the contention of sudden and unanticipated breakdown and acknowledge protection asserts on this premise.

Whatever the conditions, protection can't ordinarily give insurance against liabilities when there is arraignment and conviction under wellbeing and security law.

3.2 Benefits of an asset management system

During this new era many companies needed to provide a structured approach for the development, progress and expansion of all the activities undertaken on assets over different life cycle stages, that's the asset management system goal! The main key points used for aligning these activities with any company's organizational objectives are as follow:

a) Providing benefits by using an asset as itself.

It's not simple to program the implementation of a proper asset management system, due to its particular way to be customized as requested from each organization, however, even if it can require significant time effort or expense, it's not necessary to use it since it is complete entirely or fully in all of its sectors to start accruing benefits, companies can make an effort in order to identify soon in the implementation all the benefits in areas such as risk reduction, opportunity identification or process improvement, and can be used to gain stronger stakeholder support and to show returns.

The importance to use modern operation to collect or even manage, examine methodically and in detail the Asset data in order to use its results to improve companies' strength points or to analyze the weak points describes how Asset Management is data intensive and sensitive at the same time. The creation and use of these tools can stimulate and improve organizational knowledge and decision making.

Create an asset management system brings new perspectives that can also stimulate improvements in other organizational functions, such as strategy, financial aspects, HR and IT, moreover it requires to know thoroughly and comprehensively the organizational system of each company.

The Asset management system, as it is, requires a cross-functional approach, related to each organization system and is based on life cycle evaluations; consequences are providing a central point of view in order to address the issues related to organize and plan company's life cycle or integrate finance and business.

b) Providing benefits for managing cross-functional integration and business knowledge.

This system helps to gain and understand organizations' goals and performance, their risks associated with managing resources, and all the values needed to decide or plan each strategic solution, even considering all the purchase or the investments that each company needs.

Communication across a system organization, or most of them, need to be improved, same thing as relationship between customers or interaction across functions. An asset management system entirely provides these objects, by ensuring to manage asset in an integrated way, and to improve its financial value. As result, an asset management system could guarantee the sustainability of decision making and a long-term approach to companies' lifecycle.

If now we want to focus on power system reliability, the last observation could be related to financial or economic evaluation, the crucial point, but surely the clearest and most important one, even more for deferred maintenance analysis. Moreover, all the software and program for deferred maintenance or its optimization need to display and analyze economic or cost-benefit data, with the aim of determining and optimizing, improving, deferred maintenance lists.

It's clear that there is the necessity to involve all relevant knowledges and functional instruction that concern with specific solutions, in order to make the long-term productivity as great as possible. It's necessary not to determine a 'silo thinking' with all the functions, such as, IT, HR, deferring maintenance, strategy or operations, organizations results are surly related to the budget planning or their controlling, that will be obtained with not enough estimation and careful thoughts for their performances. There is the needing to work in cross-functional teams, especially for top management specialist, in order to take decisions for the best of the organization, but moreover to maintain working the maintenance control program to defer it as much as possible and to meet the performances expected.

It's obvious that a lot of companies wants to use a more economic method to evaluate and improve deferred maintenance strategy in order to improve the reliability and availability, even if efficiency and safety could be improved by resuming the official asset. Companies have to choose which alternative solution to adopt, and it is addressed and extremely related to Quality and Finance, Maintenance, Operations, Safety, ensuring an exclusive strategy and cost-effective investment.

That's why the most cost effective long-term investment is chosen by comparing 'Whole Life Costing' and 'Life Cycle Costing' but, unfortunately, choosing the best of one evaluation doesn't let companies to address the 'Optimal total life cycle costing', as the illustration shows:

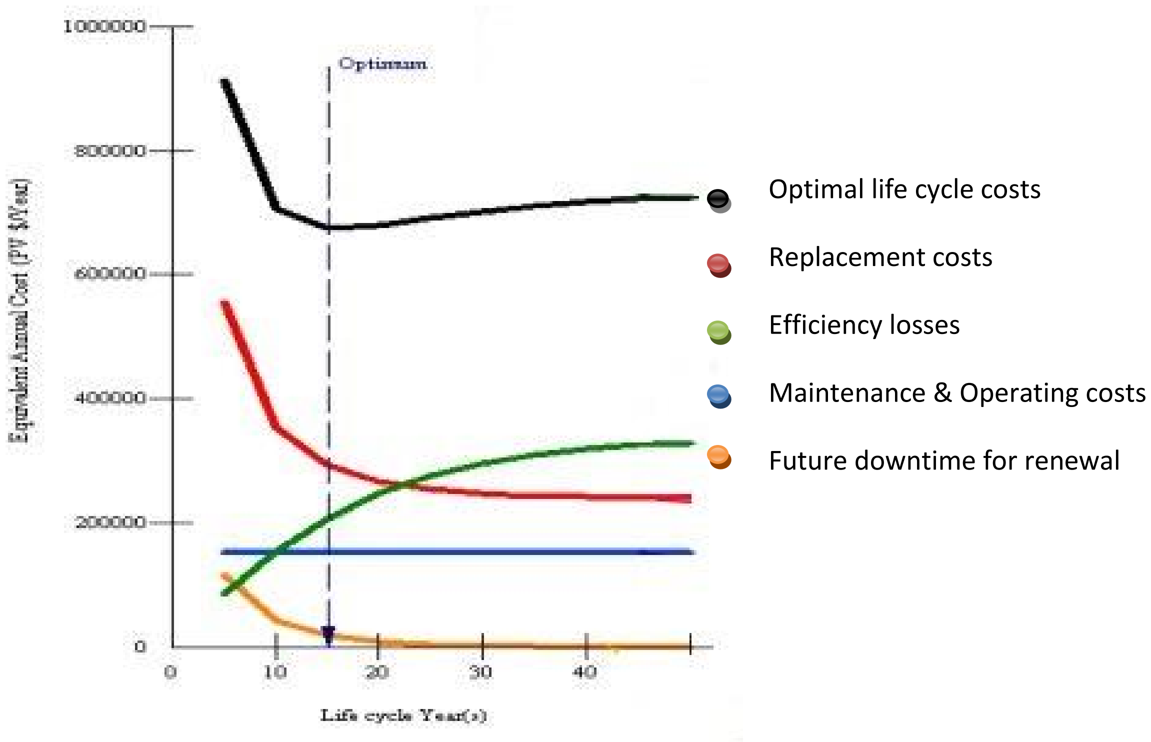


Figure 13 - Cost effective investment

As can be illustrated in this figure, each new asset requires in theory an optimal time to replace it in the future that is about 15 years' time, according to Asset Management solution. However, without this type of modeling, each company could decide to focus on the best period related to efficiency loss or keep the old asset till the best replacement date, such as replace it between 30 to 50 years.

Using the asset management solution could improve cost effectiveness companies between 5 and 10% and these values could help organizations not to go out of business, or moreover to be a multinational leader!

Furthermore, it's necessary to find out the correct time to change the old asset to the new one. An example of a model to identify the optimal time to change from the existing asset to the new choice of asset is illustrated below:

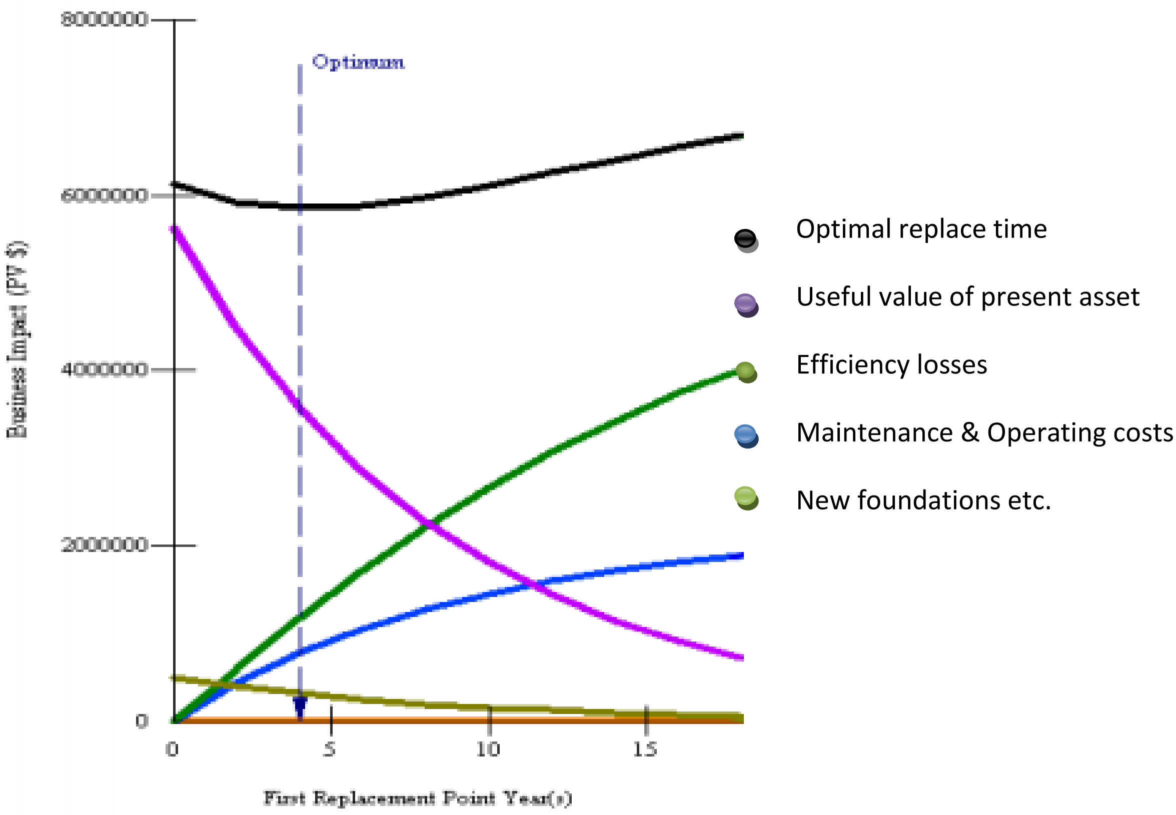


Figure 14 - The optimal replacement time of the old existing asset

As showed in this figure, the ideal supplant time is between 4 or 5 years' the ideal opportunity for a general sort of advantage. This is acquired by assessing and consolidating the helpful estimation of present resource with the productivity misfortunes, as the figure above appeared, focusing on the costs identified with Support and Task. That time anticipated that could be sufficient would enhance operational methodology identified with conceded support keeping in mind the end goal to increase here and now benefits. Doing it in less time, similar to 2 or 3 years, could change the methodology approach.

Another imperative aptitude in Resource Administration is identified with working with poor or non-existent information. A few ventures could have an incredible variety in inputs that can be more productive than a portion of the less savvy extends even in the most pessimistic scenarios. It's not generally asked for to evaluate contributions to choices, some of the time even on the grounds that there is a clear absence of time to do as such. Notwithstanding, the fundamental objective in these circumstances is getting the best data as of now accessible and utilize them with building judgment, evaluating for the most part the farthest point cases, the best and the most exceedingly bad ones.

This strategy is a snappy method to empower the assessment of arrangements whether there is an advantageous instance of use or not.

The link between a proper asset management set and deferred maintenance intervention is described in the following section.

4. Methods to evaluate risks and opportunities for deferred maintenance interventions on aging equipment

When evaluating plant maintenance, the primary key requirement is to take care of the equipment as it is, and keep it in good operating condition, by responding to its need. However, in a business context, it's important to understand that maintenance is not the best ambition. The most important goal for a company and the expected equipment-intensive business is having equipment performing functions with high reliability to lead to its business purposes. That's why maintenance, and the best way to defer it, is a valid contribution to equipment reliability and availability through its method based on proven actions, techniques, and data analysis, in order to prevent plant damages.

One weakness of this methodology is surely that in some companies, this method is often not well understood or underestimated, used to prevent damages and then fix them after the equipment breakdown, by performing preventive maintenance (PM). This "fixing method" is often seen as a relationship between customers, the production in our case, and supplier, maintenance, rather than an asset management based on the organization wide partnership for a wide reliability and availability. Moreover, if companies consider maintenance as a department, without paying attention to the results or, worst case that happens most often, using collected data in an inappropriate way, rarely it's possible to make equipment reliable. It is not important to focus on the maintenance method, its way to maintain equipment, the process, as it is, could be performed by maintainers, operators, engineers, or contractors, this does not take away safety issues and doesn't address all of the causes of unreliability. Most of the time, maintenance is not the ultimate remedy/solution.

Hence the need to introduce new capabilities arises for the design of operations in order to improve the ability to perform a risk-based decision making based on big data collected from the field and, whenever possible, integrated with the DCS (Distributed Control System) data.

Every power plant owner expects not to have excessive damage and manage these plants by operating at lower cost. Unfortunately, plant operations and maintenance (O&M) expenditures rising costs at a rate faster than inflation are describing the necessity to introduce methods more and more specific to minimize costs. To stay competitive, it is better to understand the underlying nature of plant O&M costs, and take measures to use this knowledge to their advantage.

4.1 Historical Evolution of Maintenance

Before the industrial revolution in the XIX century, there was a concern nor a necessity for the existence of maintenance, this was related to the fact that manufacturing products was made manually and in a small scale. However, after this period, with the industrial revolution a major quantity of equipment was introduced in many plants, and to this the maintenance of those equipment was extremely related, with the consequence that leading engineers and business owners to start having a bigger concern with maintenance and the way to defer it. In 1930, because of wars, military units needed to combat units and materials in better state of conservation and operation, so the concept of maintenance began to take hold.

After the Second World War, in 1950, thanks to the industry reconstruction, the market competitiveness had an increasing develop. This was also caused by a sudden increase of industries, therefore of used equipment, for which it was necessary to impose in an ever more marked way the concept of maintenance, how to prevent it or at least keep it under control. As a consequence of the high demand these machines were subjected to, it was necessary to prevent any kind of damage, above all for the benefit of safety of the plant and, moreover, the operators. In order to avoid such conditions, it was demanded by the Production Departments a more careful maintenance of the equipment, which lead to the development of Preventive Maintenance, it is necessary, however, to focus on this concept, based on the fact of ensuring maintenance far from any form of monitoring as it is, but based on simple supervision, so, once happened, the damage was taken care of but in no way was it possible to prevent it.

The development of the 1950s, based on informational technology, namely the introduction of the computer and an increasing of production techniques accelerated the birth of new maintenance techniques, based on the prevention of equipment damage, such as the indication of eminent failure occurrence, decreasing the need for periodic intervention procedures to equipment. Thanks to the introduction of measuring devices that enabled real time monitoring of equipment conditions, the implementation of microelectronics allows the detection of failure occurrences on those equipment. It was then created a new type of maintenance: Predictive Maintenance.

Niebel (1985) referred that in 1981 only 1 to 12% of employees of industrial organizations worked in maintenance departments, instead, nowadays, there is a continuous growing need of departments totally dedicated to predict maintenance, mostly caused by the increasing use of automation and reduction of manual work, which has caused a remarkable modification and amplification on those departments. Figure 12 shows the temporal evolution of maintenance since the 50s decade, the period in which it has gained more prominence.

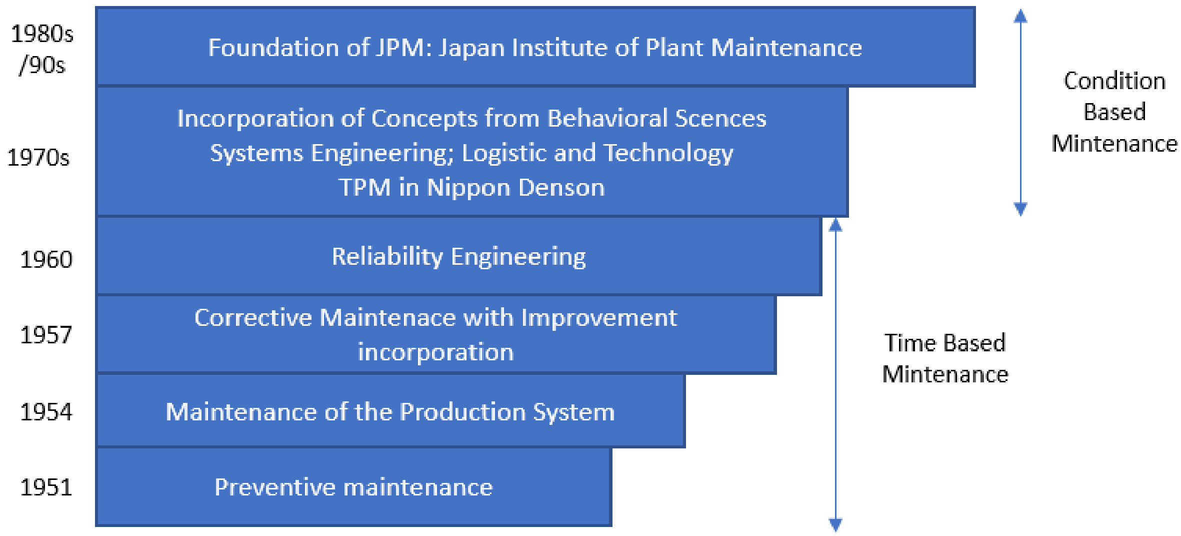


Figure 15 - Temporal evolution of maintenance

The last generation maintenance, i.e. proactive maintenance provides the role of technical diagnostics, as it has increased its importance and it is possible to gradually move to increasingly complex and cutting-edge maintenance systems, such as Total productive maintenance (TPM) or Reliability-centred maintenance (RCM).

4.1.1. The concept of Maintenance

The European standard of Maintenance Terminology assumes that maintenance is *"the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function"*. It is a set of organized activities that are carried out, with the minimum possible cost, in order to keep an item in its best operational condition. Such activities, like repair and replacement, are necessary for an item to reach its acceptable productivity condition.

The maintenance phenomena involve a certain number of operations that are carried out guaranteeing the lowest possible costs able to guarantee the reliability of a system, equipment or plant.

A standard monitoring is based on a series of operations that occur during the working day, which are of vibration or temperature variation, for example.

On the other hand, at an economic level, maintenance is aimed at ensuring that the experience of an appliance during its entire life cycle and ensuring that the safety of the structures in which the equipment is used is not put at risk. staff who manage it.

4.1.2 Types of Maintenance

There are different types of maintenance used in the industry, related to the main principal company's requests. Depending on the way of proceeding in relation to a given anomaly or failure, the maintenance interventions can essentially be separated in two categories: planned and unplanned maintenance. The difference between the two is based on the status of the equipment, in particular the unplanned one occurs when equipment failure happens in such a sudden and unpredictable way that it doesn't allow for a planned action.

Reactive Maintenance

Responsive support is a spontaneous kind of upkeep where no moves or endeavors are made to keep up the hardware as it was initially arranged by the fashioner with a specific end goal to guarantee that plan life was come to.

Studies demonstrate that this kind of upkeep is as yet a standout amongst the most utilized because of its low capital cost and low work needs. In any case, this is frequently misjudged, in light of the fact that in spite of the fact that this approach in the brief timeframe has bring down expenses, as a general rule, amid the time that is accepted to be investment funds in support and capital expenses, there is being spent more cash than it would have under an alternate upkeep approach. This happens on the grounds that while sitting tight for the gear to break, its life is being abbreviated, bringing about a more regular substitution. This expanded cost would not be experienced had the upkeep program been more proactive. Likewise, the work costs related with the repair will in the long run be higher than typical in light of the fact that the disappointment will in all likelihood require more broad repairs than would have been required had the hardware not been hurry to disappointment.

Corrective Maintenance

Performed after the event of a sort of disappointment that does not permit the encouragement of the gear's action, remedial support is a kind of upkeep wanted to re-establish the hardware's capacity to perform such exercises. It can be performed immediately after the blame has been identified or with a postponement as indicated by given support rules.

This support write is more qualified when:

- The gear's activity isn't significant for the beneficial procedure;
- The cost of repair is low;
- There are no wellbeing related issues.

Restorative upkeep can be separated in two unique classes: conceded and therapeutic.

Conceded restorative support is performed after the disappointment event. It re-quires the suspension of gear's action and is performed to immediately settle the hardware while sitting tight for the medicinal upkeep movement, which will settle it effectively and forever. Therapeutic restorative upkeep has the target of treating the reason for disappointment. It is gone before by an essential driver examination with the reason for checking if there is constrained or normal corruption, with a report being made after the enlisted event.

Preventive Maintenance

Preventive maintenance (PM) is performed in pre-decided periods or as per affirmed criteria with the goal of lessening the likelihood of gear disappointment. A viable preventive support design ought to incorporate arranged substitution of parts and symptomatic measures. By bringing the component of arranging into the support capacities, the repair and labor prerequisites can be diminished.

Preventive support is an imperative progressing mischance counteractive action which ought to be incorporated in the tasks of the assembling forms. A portion of the benefits of this sort of upkeep are:

- Improved framework unwavering quality;
- Decreased expenses of substitution;

- Decreased framework downtime;
- Protection of benefits;
- Prolongation of hardware's helpful life.

Predictive Maintenance

Predictive Maintenance endeavours to distinguish the beginning of a debasement instrument with the objective of redressing that corruption preceding noteworthy disintegration in the segment or gear. The demonstrative abilities of prescient support advances have expanded as of late with progresses in sensor innovation, and all the more as of late with another IT idea known as IoT (Web of Things). The field of prescient support innovation has turned out to be progressively complex and innovation driven, making basic the right preparing of administrators with a specific end goal to appropriately utilize the apparatuses it gives. The expansion in upkeep innovation enabled organizations to utilize Condition Checking programming as an instrument to give more precise Condition Based Support (CBM), a basic segment of prescient upkeep.

Condition Monitoring

Condition Checking is a procedure of ceaselessly observing operational qualities of a machine to anticipate the requirement for upkeep before a disintegration or breakdown happens. Condition checking can possibly enhance operational effectiveness by enhancing the unwavering quality of activity and machine up-time. The observing should be possible through non-nosy strategies, for example, temperature checking, oil particulate investigation and ultrasonic examination; and additionally, meddling procedures, for the most part transducers mounted on the hardware that measure parameters, for example, vibration, temperature and weight.

Predictive maintenance procedures utilize constant or occasional condition observing of plant and gear to decide working conditions and to recognize early cautioning pointers of disappointment.

Improvement Maintenance

This sort of upkeep is utilized when the re-foundation of the working conditions must be done through the change of the hardware, or when the support conditions, in the extent of a viability or unwavering quality change, prescribe that such alterations are finished.

4.2 Current methods and possible practical solutions

The Risk Analysis Method allows companies to adopt a quantitative analysis in order to evaluate the probability of occurrence of equipment failures in a power plant and, moreover, the related consequences for its operation, correlating probability and consequence.

The following topics are described by a Risk Analysis Method:

- Developing a data sheet structured that can support risk evaluation and consistent hazard identification;
- Developing all the equivalent severity and frequency scales for application across different business units, such as operations, maintenance, finance, HR etc,in order to guarantee an solid risk analysis method;
- Embedding this method within a risk management process in order to share and guarantee good practices across organizations.

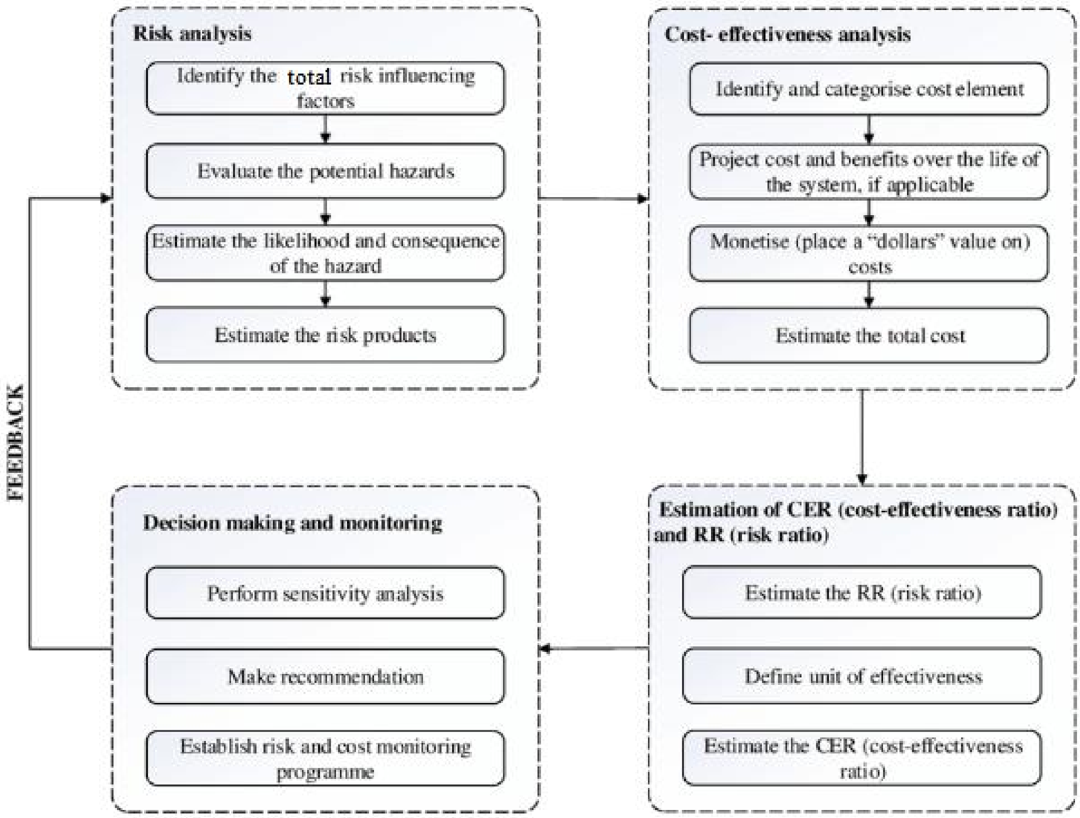


Figure 16 - Risk analysis / Cost-effectiveness ratio

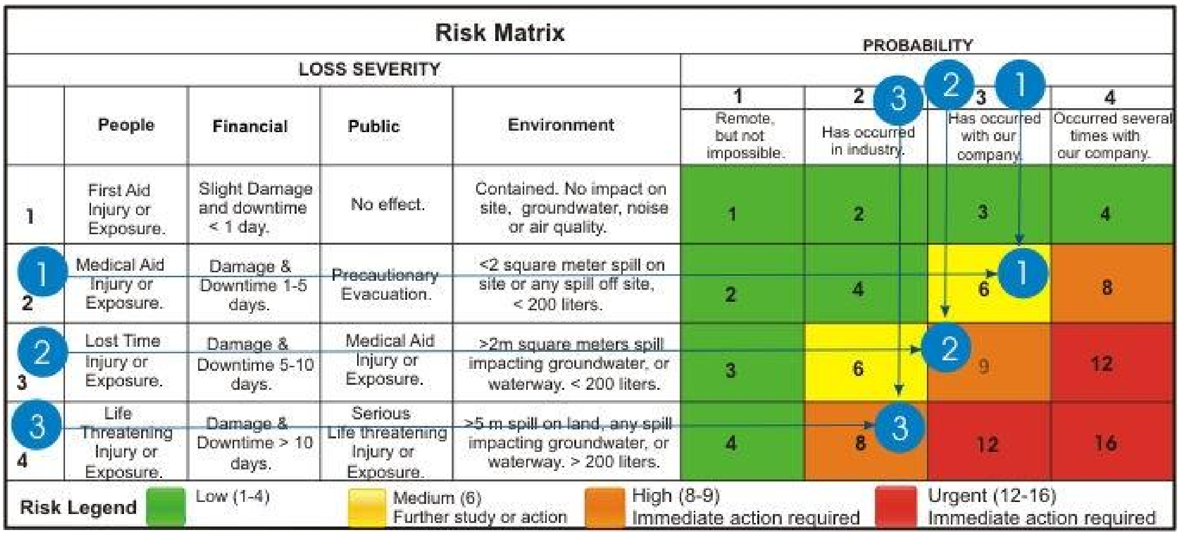
As the figure shows, the description of this method could be divided by these four areas setting, that are related to the principal deferring maintenance steps, and the dependence of each one from the others is necessarily evident. The first selection is the evaluation of the total risk influencing factors, including risks related to aging causes, and the evaluation of the potential hazards is used to identify relevant accident scenarios. These steps are powerful to estimate their consequences, and so the risk products. The second step is an analysis about the cost-effectiveness of the solution gained through the risk analysis by identifying and categorizing each single element, by monetizing the risk and estimating the total amount of costs.

An estimation of the cost-effectiveness ratio and risk ratio is necessary to define unit of effectiveness, by which make a decision and then monitor the solution, by sensitivity analysis and programs to establish risk and cost monitoring. Through this last section, companies can have a feedback to define the right solution, this is the most significant step of the Risk Analysis Method, within which evaluations are made on the operational choices that can vary considerably the financial performance of a company.

The methods used in the industrial sector for which to define a risk index are among the most disparate, both at a system level and at a graphic level. It is necessary to point out that companies need to commit the shortest time and the least possible efforts for the risk assessment, obtaining however results that are as optimal as possible Risk assessment methods are commonly used when planning equipment maintenance, in order to show the cost impact of the proposal solution, based only on the past experiences related to a specific component. In fact, this method requires a wide deal of data in order to asses both probabilities and consequences. The second steps consist of quantifying and evaluating the risk, in order to obtain a proper solution, to which is related a proper acceptability/tolerance.

New elements and methodological developments include:

- Consideration of new primary information sources to constantly improve data quality and the level of completeness;
- Estimation of external costs;
- Evaluation of new renewable technologies;



Risk Matrix					PROBABILITY			
	LOSS SEVERITY				1	2	3	4
	People	Financial	Public	Environment	Remote, but not impossible.	Has occurred in industry.	Has occurred with our company.	Occurred several times with our company.
1	First Aid Injury or Exposure.	Slight Damage and downtime < 1 day.	No effect.	Contained. No impact on site, groundwater, noise or air quality.	1	2	3	4
2	Medical Aid Injury or Exposure.	Damage & Downtime 1-5 days.	Precautionary Evacuation.	<2 square meter spill on site or any spill off site, < 200 liters.	2	4	6	8
3	Lost Time Injury or Exposure.	Damage & Downtime 5-10 days.	Medical Aid Injury or Exposure.	>2m square meters spill impacting groundwater, or waterway. < 200 liters.	3	6	9	12
4	Life Threatening Injury or Exposure.	Damage & Downtime > 10 days.	Serious Life threatening Injury or Exposure.	>5 m spill on land, any spill impacting groundwater, or waterway. > 200 liters.	4	8	12	16
Risk Legend	Low (1-4)	Medium (6) Further study or action	High (8-9) Immediate action required	Urgent (12-16) Immediate action required				

Figure 17 - Risk assessment matrix

As it is shown in the figure above, when the series of item are assessed, the risk is evaluated thought a matrix which can display and evaluate the necessity of intervention, for values 8, 12 and 16, or just the study of the injurie, if the value identified is 6. When deciding the value of the corresponding matrix, the choice of the parameters is entirely based on the characterization of the same figure, through a trivial and concise description, that's why it is assumed to be a concept dictated by the experience of each company.

As Andy Brazier suggest in his paper, a valid Risk Analysis method needs to score the tasks listed by evaluating for aspects: hazardousness, change of system configuration, error vulnerability, especially related to human errors and impact on safety devices. By using the risk matrix each task represents a value for each aspect. The evaluation of the results is made relating to the ones with the highest score that are considered the most critical.

As discussed before, the principal aim is obtaining a 'rough and ready' assessment rather than a detailed analysis, using sophisticated software, which usefulness is strictly connected to the number of data sheet disposed. In this way it could be possible to identify and score even over a 100 tasks in a day, the problem is simply related to guarantee a remarkable reliability, compared to what could be achieved through more detailed calculations and inspections.

If we have to focus on this method, the necessity to monitor and control all hazardous systems is critically evident. Furthermore, the identification and the evaluation of all the individual tasks of this type are required only in view of a more in-depth data experimentation. Same thing about the equipment control and monitoring that will subsequently undergo this type of evaluation, through a risk assessment. It’s obvious, on the other hand, that emergency response tasks are surely critical by default. Maintenance tasks are evaluated as operations tasks, even if there are some maintenance tasks presenting features that need to be viewed in a different way and observed more carefully that others, in fact the evaluation of the total score for a generical system company is influenced by the hazardousness, related to the assumption that several of the tasks, or maybe all of them, are performed whilst the system is alive, during its working phase. That’s why it is necessary to perform these tasks during the shutdown machine, in order to reduce critical issues. It’s important to create with this mind a trade-off between the impact on production related to a preventive maintenance and its task criticality.

It has been assumed that process safety method standards identifying critical tasks, must include:

- Hazard Identification (HAZID);
- Hazard and Operability (HAZOP);
- Safety Integrity Level (SIL) assessments;
- Fault and event trees.
- Process Hazard Review (PHR);

It is not enough to use these methods in order to provide enough insight into tasks to allow the priority needed by companies. This partial lack of failure is caused is by their structural approach based on several variables, not resulting in a comprehensive list of tasks. Also, because they are focused on hazard and consequence, don’t take into account the human factors indicating and strongly related to the vulnerability to human error.

However, on the other hand, they allow to relate all the most usual tasks, by providing a useful structure. Nevertheless, the cannot guarantee to demonstrate a systematic method to identify and prioritise tasks.

When a company is faced with an organizational decision, in general it has to deal with: alternatives, preferences related to each solution consequence. Each method described is able to show the alternative solutions differently, going to remark the eventual solution, even if the procedures related to decision making operations are considerably numerous. What is important is surely the choice of the best alternative related to the proper consideration of uncertainty. It is necessary to take into account risk objectives, as decision analysis has the capability to provide methods in order to establish a quantified tradeoff of preferences for performance along multiple decision.

There are two types of preventive maintenance, one is detected by the time, in order to prevent or retard the failure, made in a different interval of time even if there are some other informations available only in a specific time occurring, the particularity is that when the equipment is monitored is ready out of order; the other one type in an on-condition maintenance, condition-direct maintenance or predictive maintenance, in order to detect the onset of a failure.

The analysis obtained through reliability-centered maintenance provides a dynamic tree solution in order to show immediately the operational solutions to be undertaken. Time detected tasks are applied mostly if the hazard rate is known and there is a prevision to increasing. The analysis path has the following steps:

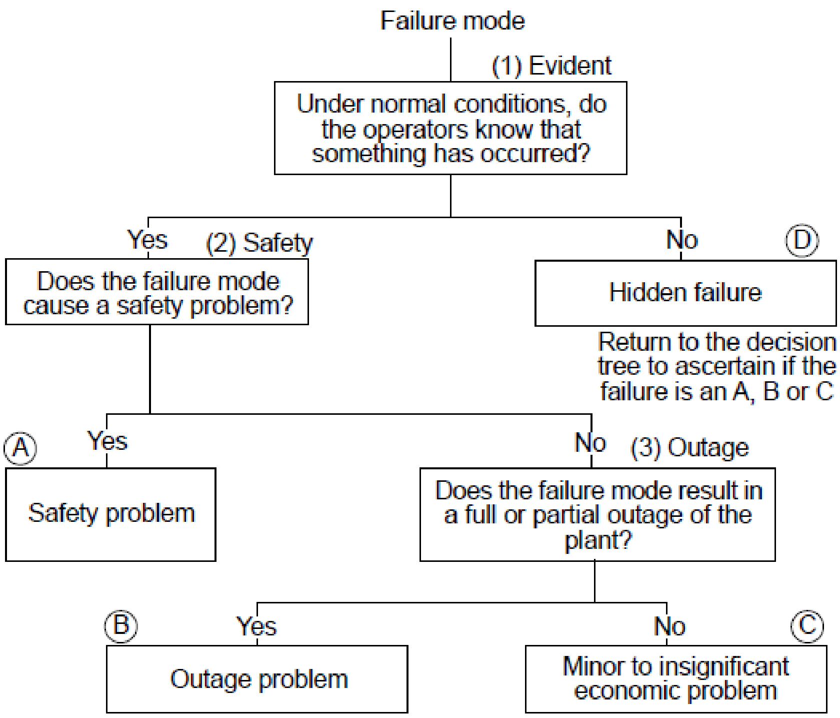


Figure 18 - Decision tree analysis in a CBM monitoring

The structured analysis process requires a successful implementation in order to eliminate the identifiable safety and environment hazards, to control and reduce the O&M costs or outages costs through increased system availability. Another classification according to the type of symptoms they are designed to detect.

4.2.1 Monetized risk values, an example from practice

How to investigate and help determine the root cause of plant issues? The first thing to do when there is the need to investigate at practical equipment is an overview of the plant, identifying the equipment that show an issue. Monetized risk values offer the opportunity to support risk-based decision making using the data collected from the field. This method, based on risk analysis concepts, uses a risk tree approach which can outline every potential failure mode of each component of each asset group.

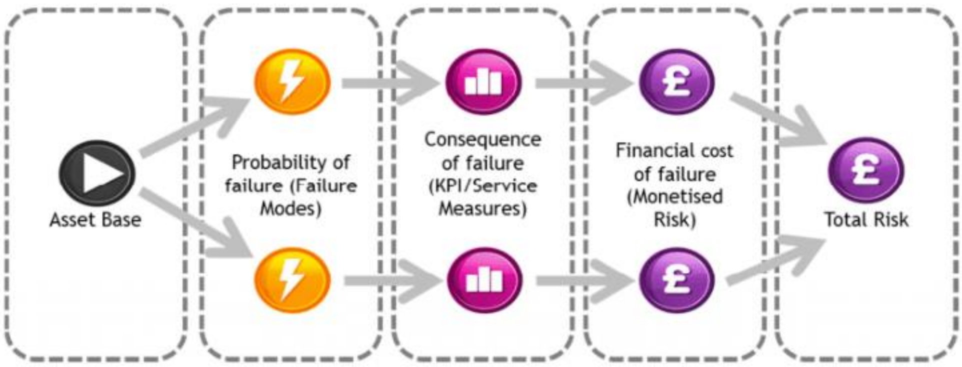


Figure 19 - Broad Monetised Risk Map Process

When applying this decision-making method on power plants equipment, first it must be focused on risk concepts in order to identify critical equipment both to guarantee power plant operational performance and availability, then it is necessary to increase critical equipment availability by involving the proposal of applying a potential risk analysis policy.

Monetised risk values requires to estimate the costs associated with each potential deferring maintenance policy, especially all the operational costs and the failure costs used to measure the consequences related to critical equipment failure for many power plant operations. After the estimation of these failure probabilities and the costs of failures, with the related operational costs, the evaluation and estimation of the index identifies and select the best maintenance policy, obtained evaluating the mitigation costs interconnected to the actual risk of each option presented. The subsequent phase is the decision criteria, based on the minimizing of the cost of failure relatively to each equipment, considering the costs and likelihood of failure scenarios manifestation.

The evaluation of the singular proposal risk will be the result of a purely singular statement, gained though risk assessment matrix consulting. In order to assess the relative importance of these risks, each response is often plotted on a two-dimensional heat map, which has the capability to underline and show the connection between the impact and the likelihood in order to demonstrate, if necessary, the monitoring require.

This method seems to be rarely applicable for each different scenario, causing its limited suitability for practical application for the companies, especially in the energy sectors, in managing power stations, since a more constant and accurate control is required, mostly for the ageing equipment in order to guarantee their best level of production and optimization.

In the following chapter, the use of existing and a proposed customised methods to identify valuable maintenance/repair overhaul options for ageing equipment through a risk based evaluation of different options is discussed.

4.3 Energy sector case studies: current methods new improved proposed solutions.

This session intended to look at some specialized hazard appraisals, to underlined what should be enhanced, however for the most part to portray the level of vulnerability and incorrectness, which is gotten from a figuring and a processional decision frequently considering specialized understanding, which would require a more prominent hypothetical premise. The method ought to be done by or with the help of the pertinent skillful individual and endorsed by the applicable authorizers.

The accompanying strategy is connected to the investigation of three contextual investigations in a power age organization over various area in the Republic of Ireland. As a major aspect of an on-going procedure of Process Wellbeing change, the association recognized a need to propel the distinguishing proof, examination and administration of dangers over the business, and to hold these dangers in an organization that encouraged correlation and following. A task group was in this way gathered, with agents from various stations and specialism, to make a hazard examination strategy fit for addressing the business' needs.

The principal case is about a Generator Rotor center in a dam. This is created from basically fire cut carbon steel and of welded development. The external edge of the rotor had a progression of stacked steel overlays appended onto which the rotor posts were joined. The deformities that have been distinguished give off an impression of being to a great extent identified with poor welding method/system amid development. In this way, the hazard comprises to not address potential imperfection, causing basic disappointments of rotor center point in benefit, causing a recognizable effect, for example, harming the generator posts/stator and perhaps harming work force.

To keep this marvel the organization needs to choose when to supplant the rotor and if do this substitution utilizing a recently composed part. These inquiries are replied with a specialized hazard appraisal accomplished by concentrating on specialized/operational contemplations, together with business ones around the conceivable pertinent arrangements and how they could be acknowledged, recognizing all the basic perspectives through the help of a hazard grid and relating financial and probability interims to help the important situations seriousness and likelihood estimations.

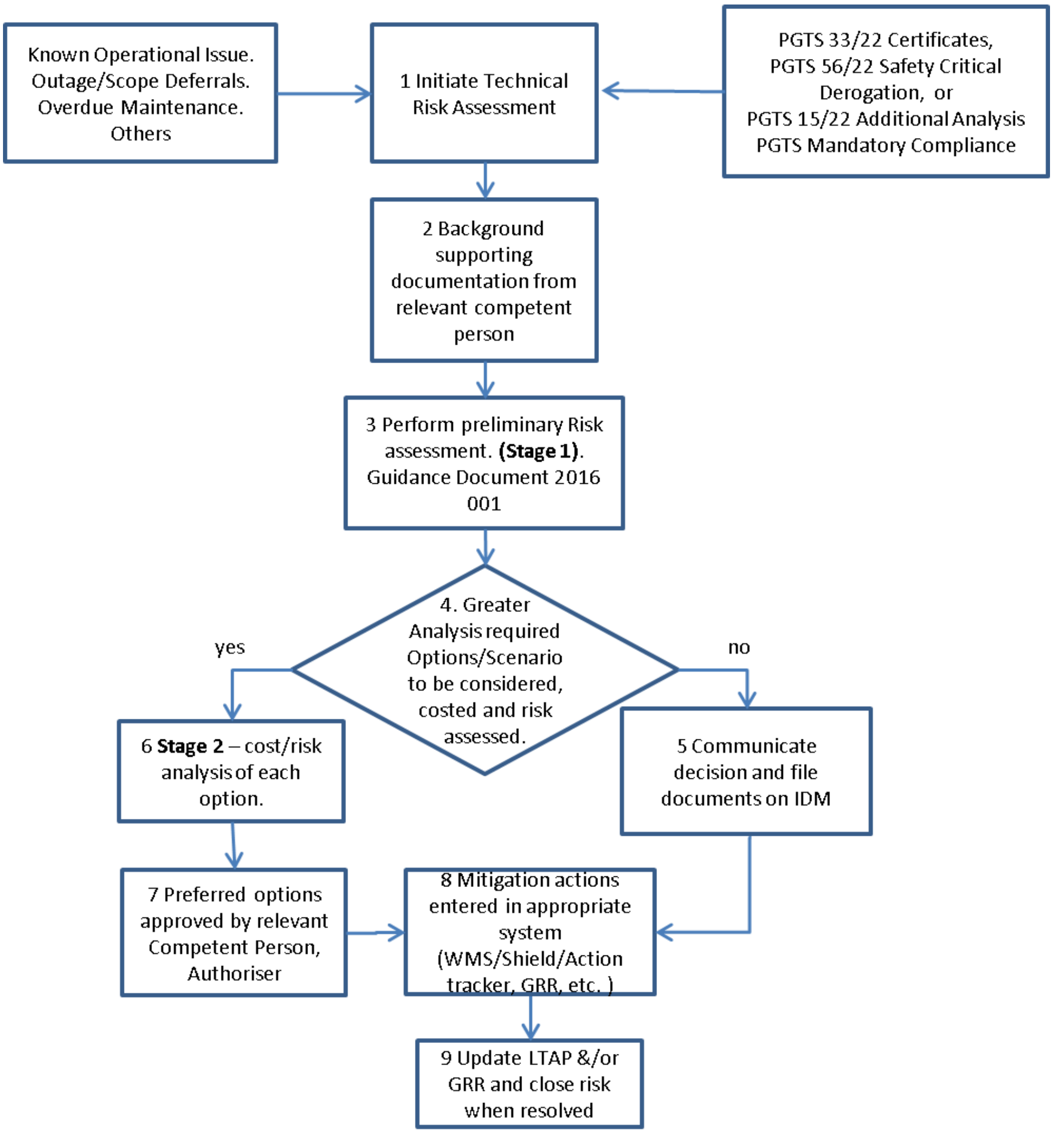


Figure 20 - Overall approach for risk evaluation of interventions

The second example concern the enhancements that could be acquired by utilizing a more particular and itemized technique, underlining the contrasts between the past approach. This is appeared by the investigation of a HP turbine module sidestep valve station. The disappointment in this examination was an aftereffect of Strong Molecule Disintegration (SPE). The starting point of the strong particles is erosion of the coating of the high-vitality pipework, because of maturing of the funneling lines joined with a working administration prompting more prominent warm cycling. The expanded length between blackout/repair openings additionally prompt an expanded presentation to the impacts of disintegration.

Since the disappointment some work has been done to moderate the danger of harm from SPE. For example, particularly essential changes to the tasks of hot and chilly begins and observing for conceivable SPE harm. After a proper examination between the different choices, for every last one of them a hazard investigation has been set up, the best arrangement was acquired by recognizing the effect rating, its likelihood and its hazard utilizing the classes bolstered by assessing a scope of dangers identified with the choices the organization is looking for repair and the results identified with the lingering hazard too.

While there are no apparent dangers to faculty wellbeing a long haul constrained blackout would have immense money related ramifications, chiefly caused by the need to repair the unit, which has an extra time to fabricate another module. The likelihood rating has been chosen because of the way that SPE is for the most part a known component on those units, to which the consciousness of the plant age must be included, yet in some cases it could be only caused by an inaccurate examination, that didn't report the harm watched. The potential relief activity was revamping the extra HP module to diminish the term and budgetary effect of a constrained blackout. This hazard evaluation considers the dangers of harm to the drive wheel. The accessibility of an extra HP module was additionally viewed as a factor ready to decidedly influence blackout length.

The investigation was directed utilizing adapted hazard contemplations. The alternatives accessible are plot and surveyed underneath:

- Option A: Supplanting of valve station with configuration move up to moderate know issues.
- Option B: Supplanting with same plan valve.

After the hazard appraisal for the present circumstance, every alternative was poor down into the real expenses of the arranged intercessions in addition to the adapted estimations of the hazard associated with the mediation itself; the leftover hazard left after the mediation was additionally at that point assessed.

A total of hazard appraised costs was then figured by considering for every choice the loss of income specifically corresponding to the timeframe expected to play out every intercession design, the genuine repair costs, assessing every one of the parts included, for example, materials, gear, work and so on the moderation costs that allude to the choices concerning occurrence a supplanting with a similar outline, could be gotten thinking about nonstop upkeep administration. What's more, considering the execution punishments that could likewise be associated with the choices, (for example, failure to keep running at full speed control and so forth.)

A hazard appraised cost was additionally considered for the conceivable situations influencing the genuine Wellbeing and security or potentially process danger associated with the intercession work arranged, (for example, working at stature etc..). No reproduction or iterative count is supporting this assessment as it essentially requires master judgment from the benefit administration group with a proper grapple point to legitimize the picked gauges. To wrap things up the strategy required to assess an adapted hazard estimation of the remaining danger left after the mediation through which an estimation of the hazard evaluated advantages can be in this manner added to. The hazard appraised advantage utilized for organizing the alternatives is just gotten by contrasting the advantage given by the present hazard presentation less the leftover hazard introduction against the costs which is acquired by the assessment of hazard evaluated expenses of the different alleviation designs as clarified previously. The higher the advantages the better the choice.

Station: and unit:	
Purpose of Project and brief Synopsis:	
Existing Condition (issue being assessed):	
Existing derogations and or attached documentation	
Brief summaries of possible solutions	

Risk assessment of current situation:

Categories		Description	rating	results
Loss of revenue	cost of 'GWHR loss' Link to Portfolio Income			
	Likelihood			
	Risk rated cost (€)			0
Plant damage cost (insert justification here)	Cost of repair/ replacement			
	Likelihood			
	Damage risk rated cost (€)			0
Safety (insert justification)	Safety cost			
	Likelihood			
	Safety risk rated cost (€)			0
External Stakeholders/ PR (justification)	PR cost			
				0
Environment	Environmental cost			
	Likelihood			
	Environmental risk rated cost (€)			0
Sum of risk rated cost for current status				0

Figure 21 - Template used for risk evaluation of current situation

		Option A:		
Categories		Description	rating	results
Loss of revenue	Best estimate Availability loss (no. of days)			
	Likelihood			
	Risk rated cost (€)			
Repair cost 1	Best Estimate Cost of repair/ replacement			
	Likelihood			
	Risk rated cost (€)			
Mitigation cost	Best estimate for Mitigation cost			
Performance penalties	Best estimate for possible loss of performance			
Others	This may be performnace enhancement or reduction			
Safety exposure for work (insert justification)	Safety cost			
	Likelihood			
	Safety risk rated cost (€)			
Sum of option cost				€0
Residual risk of situation after option A		Description	rating	results
Loss of revenue	GWHR loss			
	Likelihood			
	Risk rated cost (€)			
Plant damage cost (insert justification here)	Cost of repair/ replacement			
	Likelihood			
	Damage risk rated cost (€)			
Safety (insert justification)	Safety cost			
	Likelihood			
	Safety risk rated cost (€)			
External Stakeholders/ PR (justification)	PR cost			
Environment	Environmental cost			
	Likelihood			
	Environmental risk rated cost (€)			
Sum of risk rated cost for residual risk				0
Total Risk Rated Benefit				€0

Figure 22 - Template used for risk evaluation of various options

4.3.1 A new prospective for the risk assessment: the dynamic decision analysis

It is detectable how valuable, attainable could be the usage of the choice trees ready to characterize an answer for any sort of hazard appraisal. The technique ought to have the capacity to apply the best arrangement even in another plant, with an alternate estimation of the hazard, however organizations can have a more exact choice strategy utilizing that one. Enhancing the administration of maturing gear ought to be gotten utilizing these strategies. Market request commits organizations to influence the maturing plant to work harder, making the most need apply a legitimate hazard evaluation with its motivation investigation.

A decent beginning stage for the advancement of the coherent probabilistic model can be an utilitarian investigation of the framework, abusing likewise, where accessible, the data contained in the examination as of now continued with customary procedures. The last contextual investigation was about a typical methodology for LP rotor gas turbines hazard appraisal in which the choice was partitioned in:

- Option 0: LP Module cover lift for examination, without new cutting edge put away,

- Option A: LP Module cover lift for review, with a supply of new edges put away (7 cutting edges are generally put away, in view of the past organization encounter)
- Option B: LP Module cover lift and substitution of the considerable number of edges.
- Option C: LP inward square substitution (rotors and transporters)

Every choice has an alternate workscope and cost, related to a hazard rating in view of the hazard framework, increased through a conceivable estimation of the effect and the likehood of the arrangement embraced. In this investigation, a dynamic occasion tree technique was utilized to figure the likelihood of the gas turbine edge break. It depended on an auxiliary dependability investigation so as to measure the conduct of a few basic segments of structures subject to dubious loadings, limit and geometrical conditions and material parameters. (H. R. Millwater, Y.- T. Wu, 1993) Turbine disappointment modes are by and large depicted by recurrence, push consumption and disintegration, crawl weakness; the calculation of the likelihood of disappointment requires the determination of a specific pressure condition, fuction of time.

4.3.2 Integrated Dynamic Decision Analysis, logical model

The Integrated Dynamic Decision Analysis (IDDA) - described by Remo Galvagni (1984; 1989) - permits to bear on the hazard examination powerfully, considering process time dependant events, improvement of systems for LPG tanks upkeep and testing (Gerbec, Baldissone, and Demichela, 2016)

IDDA is a Figuring Situation for Coordinated Dynamic Choice Examination. As Choice Investigation apparatus it depends on a thorough use of Rationale to characterize and to portray all the conceivable option contradictory situations among which the decision must be finished. Every elective situation is created and introduced by a Reason Result coherent approach. In this approach both sensible principles and likelihood assessments are connected powerfully in that each snippet of data dynamically got can be utilized to characterize the progressive legitimate way and the contingent probabilities of the accompanying occasions, as indicated by a sound use of the inductive thinking.

IDDA strategy depends on a sensible probabilistic displaying of the framework, coordinated with its phenomenological demonstrating. This model collects a reinforced occasion tree, keeping in mind the end goal to make sense of the rundown of levels worked through an utilitarian investigation of the framework, to make a reticulum for the sign of the consequent levels that must be gone to, identified with every arrangement reaction, to dole out a likelihood incentive to each level recognized, that speak to the disappointment event expected, and, last activity, to characterize coherent and probabilistic confinements, that can permit to fit the changed run time of the model to the present mindfulness status.

The consistent probabilistic model is expounded on account of a successful learning of all the conceivable situations uncovered in the imput show, deciding an assessment of all the conceivable arrangements of occasions that the framework could experience. Together with the sensible demonstrating, a phenomenological show must be set up to portray the physical conduct of the framework. Obviously, there is a need to include a phenomenological display that can portray the physical conduct of the framework. This model could impact the ststus of the intelligent model going to adjust it depicting the genuine conduct of the framework, or its reaction to a conceivable harm case, for example, that which could be produced at the season of breaking down of a hardware and how it impacts on the other, if the framework can respond to this issue, ensuring that it can forestall it, or if a close down of the framework is essential. Along these lines an immediate gauge of the outcome for each arrangement is ensured, keeping in mind the end goal to get a gauge of the hazard, the evaluation of the general danger of the framework and the normal estimation of the results.

The IDDA examination was connected in Baldissone et al. (2017) to formaldehyde plant generation, in Baldissone et al. (2014, 2016) to a VOCs treatment plant and Demichela (2014) to the hazard construct configuration in light of an allyl-chloride creation plant. The cooperation between logical– probabilistic and phenomenological model could be effectively appeared in the figure above.

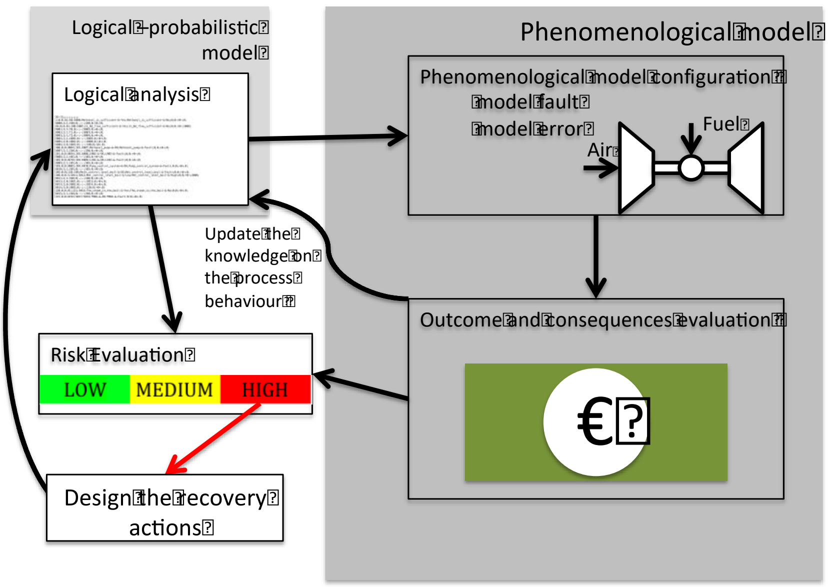


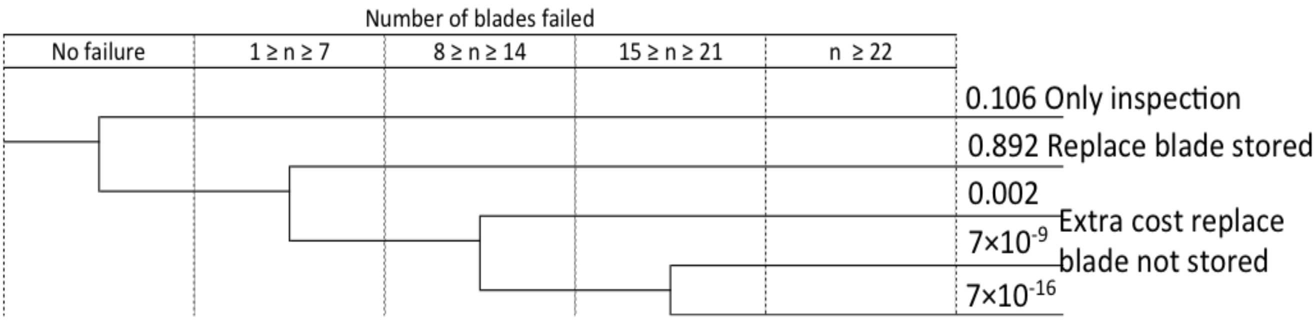
Figure 23 - The interaction between logical–probabilistic and phenomenological model

This logical-probabilistic model, in view of the general rationale hypothesis, is worked by its own particular syntactic framework to shape an upgraded occasion tree structure, through:

1. The utilitarian examination of the framework and the development of a rundown of levels, with inquiries and confirmations on the usefulness of every component; each level speaks to the basic matter of the legitimate model and furthermore a hub in an occasion tree;
2. The development of a 'reticulum' showing the addresses (resulting level) to be gone to relying upon the reaction in each level, and a remark string that enables the client to peruse the legitimate improvement of an arrangement;
3. The relationship to each level of a likelihood esteem, which speaks to the normal level of event of a disappointment or an undesirable occasion and of a vulnerability proportion, which speaks to the dispersion of the likelihood.
4. The meaning of the intelligent and probabilistic requirements, which permit adjusting the run time of the model, fitting it to the present learning status.

The elaboration of the intelligent – probabilistic model, depicted in the information record through the IDDA programming, restores all the conceivable groupings of occasions that the framework could experience, contingent upon the learning uncovered in the information demonstrate, together with their probabilities of event.

In the coherent displaying of the diverse alternatives, it has been considered how the upkeep techniques are carried on relying upon the quantity of damaged blades.



This figure shows, for clarity sake, the Event Tree representation for the option A (H. R. Millwater, Y.-T. Wu, 1993).

A phenomenological demonstrate, together with the coherent displaying, must be set up keeping in mind the end goal to portray the physical conduct of the framework. The phenomenological model could impact the refreshing of the consistent model producing a superior depiction of the genuine conduct of the framework, i.e. showing if, after the disappointment of a bit of hardware, alternate segments can remunerate its lack and finish the task, or if total impacts can show up and veer the framework from its typical conduct.

The phenomenological model can give an immediate estimation of the outcomes for each single arrangement keeping in mind the end goal to acquire a hazard estimation, the assessment of the general danger of the framework and the normal estimation of the result. The last is computed as a weighted normal of the results, as indicated by their likelihood.

The phenomenological demonstrate permits figuring the expenses for the diverse upkeep choices for every situation depicted by the intelligent model. The basic expenses have been provided by the plant administration.

Through this model the accompanying outcomes have been acquired: Choice 0 (no extra parts put away) has a danger of 2023k€, that declines to 1845k€ for Choice A (7 sharp edges put away), since the extra parts are accessible and no plant trip is required longer than the arranged one. Choice A demonstrating additionally affirms the organization choice on the quantity of cutting edges to be put away, since the disappointment of 7 sharp edges or less is the one that demonstrates the higher likelihood of event (around 99%).

The hazard increments for the other two alternatives: Choice B demonstrates a danger of 3399k€ and Choice C of 5799k€, since in the two cases the substitution of the considerable number of cutting edges (Choice B) and furthermore of the rotors and bearers (Choice C) include higher expenses.

Then again, these two last alternatives have as an outcome an augmentation of the upkeep time frame: 8 years for the B and C Choices against 4 years for 0 and A Choices. Accordingly actualising the hazard esteems to the yearly support chance, the accompanying figures are gotten:

Choice B with a hazard estimation of 425k€/y has all the earmarks of being the most advantageous, against the 461 k€/y for Choice A, 506k€/y for Alternative 0 and 725 k€/y for Choice C.

Choice C has all the earmarks of being in the two cases the less advantageous, however it ought to be viewed as that the total remodel of the inward parts of the turbine should convey likewise to a change of the plant efficiency, that ought to repay the higher speculation costs. Unfortunately, the profitability information was not at present accessible when this paper was expanded, accordingly the model does not consider right now this perspective.

4.*3.3 Reducing risks through good engineering*

As examined above, the vast majority of mechanical gear is these days utilized past the valuable life anticipated at the plan organize. To keep up the asked for efficiency level and the operational wellbeing the gear in this manner require a more regular support. The additional support requires additional costs that should be upgraded, regarding recurrence and viability, against the possibility of reestablishing the hardware itself.

This thesis has portrayed three contextual investigations where this issue has been tended to through subjective and quantitative techniques ready to help the operational improvement in the mechanical space.

We ought to dependably be searching for designed arrangements on the grounds that, not at all like gentler controls, they are constantly present and unsurprising. The outline phases of a venture are the best time to actualize designing arrangements. Once a framework has been constructed it is significantly harder to roll out improvements and they may bring about higher and potentially sudden hazard. The target lessening hazard through great building is to plan frameworks that are anything but difficult to use without blunder. This needs to incorporate all methods of activity (e.g. ordinary activities, startup/shutdown, and crisis) and support.

And no more essential level this is worried about ensuring individuals can get to valves, measures, instruments, test focuses and so forth; mulling over what they have to do with these things, including utilization of devices and gear. The standards of Undertaking Danger Administration enable us to go past the essential designing contemplations. It is hard to give nonexclusive cases of what to pay special mind to however the accompanying cases from ventures I have been engaged with may give a few thoughts:

- Two indistinguishable compressors orchestrated as an identical representation – improves the probability of activity or keep an eye on wrong question blunders;
- Four compressors organized in line, related coolers masterminded in sets, one before the other – another case of improved probability wrong protest mistake;
- Instrument air compressors situated a long way from control room – reaction to trip errand requires brisk access to endeavor restart, thus they ought to be closer the control room;

- Drains vessel measured to take substance of framework – a few undertakings may expect framework to be depleted at least two times one after another, so vessel should be bigger;
- 'Batch pigging' including two circles being propelled one after another, with concoction slug in the middle of - venture had determined manual pig propelling, requiring depleting, venting and cleansing each time. Administrator might be slanted to overlook or abbreviate the length of key advances. Mechanized pig propelling would be vastly improved;
- Chemical conveyance offices intended to acknowledge distinctive chemicals, some of which would be incongruent – one of a kind association determined to kill blunder potential.

The truth is that tankers regularly land with connectors, so the advantage of special associations is significantly diminished.

Most outline audits tend to center around physical courses of action of plant and gear. Taking an errand see drives organizations included making diverse inquiries and testing whether the plan will enable individuals to do the undertakings they have to in a protected and effective way.

5. The need to structure and manage digitised shift handover for process safety

The focus in this session is on shift communication in general and shift handover in particular. The goal using effective shift handover is the communication, requiring adequate, meticulous and precise communication arrangements between operators strictly related to the risks and hazards of specific situations.

Every organization requires more discipline and application to communicate in a successful way, moreover is especially important where there are relevant major hazards interrelated to the nature of the single operations. Think about offshore stations, and the circumstances arising from the nature of the work for which there is a difference between stations and offshore, but a certain compatibility of the data must be guaranteed.

The study and implementation of these shifts stems from the errors that have occurred over the years, causing damage at a quite large level (HSE 1999; Lardner 1992) is described as follw:

'Effective communication is important in all organizations when a task and its associated responsibilities are handed over to another person or work team. Critical times when good communication must be assured include: at shift changeover, between shift and day workers, between different functions of an organization within a shift (e.g. operations and maintenance) and during process upsets and emergencies.' (HSE SH)

5.1 Accidents due to communication failures

Brazier & Pacitti (2008) provided a useful review of accidents due to poor communication and issues around Shift Handovers. The explosion in Bruncefield (England, 2005) for instance was mostly caused by reduced monitoring condition and poor communication between the operators. The operator could monitor level of the tank thanks to a gauge, unfortunately further an independent high-level switch (IHLS) was meant to close down operations automatically if the tank was overfilled.

However, at the time of the accident the gauge was stuck and the IHLS was inoperable – there was therefore no means to automatically stop the filling operation and or to alert the control room staff that the tank was overfilling (HSE, COMAH Competent Authority 2011). Eventually large quantities of petrol overflowed, forming a vapor cloud which ignited causing a massive explosion. A contributing factor noted by the official report is that the site presented three pipelines, and control room staff had little control over two of them, especially considering flow rates and time of receipt so there wasn't less than optimal information to manage the storage of incoming fuel, furthermore, it can be noted from the report how the knowledge of the damage was confusing, particularly during shift handover, causing a misunderstanding that contributed to this failure (HSE, COMAH Competent Authority 2011).

The CSB report of the BP Texas City accident (CSB Investigation Report Report No. 2005-04-I-Tx Refinery Explosion and Fire, 2007) makes a detailed study with specific reference to communication failures. This report is useful to underline the poor communication between supervisors, especially for critical information during the shift handover. The night shift operator left early, determining a subsequent brief and ambiguous night shift handover that was misinterpreted by the incoming shift. This was got worse by the failure to record steps completed on the start-up procedure by the previous shift operators. All of this was exacerbated by the fact that there wasn't a clear requirement for communication between shifts into the BP plant. Therefore, the investigation found that there were no key messages written down, but surely verbally passed by phone, and this is an event that happen in so many companies, due also to the lack of a proper sharing platform or because there is not much knowledge about it or is not paid a proper attention to the use of these platforms. This has as result that the control room and field operators did not put the right attention to this issue, closing a control valve, while the field operator was manually opening the same one.

In analyzing the available evidence during the HSE investigation for the Buncefield Major Incident Investigation Board (Buncefield, 2008), the first author's conclusions were the following (further supporting detail is available in (Wilkinson and Lardner, 2012):

- There was no positioning in place of effective arrangements for shift handover and changeover in general.
- There were not set proportionate policy, criteria or procedures for handovers.
- There were not adequately determined the key information required for communication at handover.
- When the time of the events was pressing, it was preferable to pass on a notion verbally rather than through the use of electronic shifts, losing the vision of the problems in a certain time range.
- Unfortunately, there was the possibility that some work shifts would continue beyond 12 hours, going to weigh on the skills of the workers themselves, who did not have the awareness of the actual status of the gas pipeline. (HSE 2016,b)
- Even the involvement of relatively inexperienced staff is one of the main problems that leads to incorrect use, or total non-use, of shift handovers before an incident.
- It was also noted that the previous four shifts on the pipeline were quite heavy and could contribute to an additional state of fatigue.
- Last observation, there was a lot of handovers communication failures between shifts and maintenance and operational management before the accident.

All of the above failures contributed significantly towards the accident described. The main problem was caused by the lack of communication between the operators, therefore an incorrect knowledge of what was happening inside the plant; this led to an incorrect action by the operators towards the pipeline causing a misunderstanding between the operator in the control room and on-site worker. This resulted in a subsequent confusion. Moreover, the particular activity of the pipeline and of the plant as it is causes a deeply understanding of the system in detail, in order to avoid misunderstandings like this, in order to minimize the potential human error. The event happened at night, when there are no workers inside the plant, but only individuals in the control room, this did not allow the awareness of what was really happening, contributing to making the damage worse, or at least not having the protection to act correctly quickly.

Unfortunately, this is not a new discovery. During November 1983 there was an accidental discharge into the sea of liquor material consisting of radiative waste from BNFL's Sellafield Works. This was caused, as ascertained by the Nuclear Installations Inspectorate investigation, by a failure of communication between shifts: a misunderstanding between the workers caused a tank to be discharged into the sea which was believed to contain material suitable for discharge to sea, but in fact contained highly radioactive material, creating an environmental hazard. It happened during routine annual maintenance in a plant shutdown. (HSE 2006, b) The most shocking thing is that the misunderstanding was caused by the same label that was on the tank that reported written "reactive material", but between a passage and the other one within the company, the title was transformed into "material not radiative". So, what was previously considered hazardous material, is subsequently treated as a routine wastewater. Now it is clear that with the increase in technology element used in all the companies in the world, there are more controls also through technical-chemical experiments, but 30 years ago, it was not possible to handle such errors, causing damage with a global impact.

Last example, the 1988 Piper Alpha (Scotland). This accident was caused by a disoperation of a pump that was not in an operational state. As it happens very often, in which an inactivity is discovered after a damage has occurred, the investigation found that there was no communication of the condensate pump status during shift handovers. Moreover, there was also an inconsistency in the data related to a tank located downstream of the pump that sent the liquids to the drain, going to affect also the same problematic detected by the nuclear processing plant at Sellafield in 1983, UK. (J. Ross, HAZARDS 24)

5.2 The relevance of proper communication between operators

We know that there are some natural phenomena that cannot be controlled through engineering tools, but most accidents result from human error. This is linked to the fact that the same methods of control or the tools used to do so are defined by human being.

There are two types of errors: those caused by a missed step that is necessary for the plant, and those caused by an error made in the step as itself, the first ones are defined in simplest terms, *Errors of Omission*, and the other *Errors of Commission*. It can also happen that the error is intense rather than inadvertent, caused by the fact that the operator thinks that the solution identified is optimal, even though it is not suggested. Some think that this lack of awareness causes the harm on the part of the operator, the problem, in fact, is that he knows the risk related to the error intensely, considering the correct solution they have made or thinking that the safety techniques made inside a plant we are so large that we can allow a small variation in operations. This is precisely what causes damage in many companies.

The production process of a material follows a series of stages but above all is characterized by various factors, from production, from human intervention, and the automatic functions.

A critical concept is therefore:

If an organization does not directly control risk, the organization cannot directly control quality, safety, environmental impact, or production to acceptable levels. An organization must sustainably control human error to manage the risk of accidental losses that impact quality, safety, the environment, production, or assets.

There are several reasons for which communication errors may occur, incomplete or inaccurate information may be obtained, there may be an incorrect exchange of information between a shift and another or a misunderstanding between operators. In any case, information that does not present a totality of data is affected by dangerous consequences. (Brazier & Pacitti, 2008)

Therefore, the use of a platform that is able to bring a current view of the progress in the plant, but above all that is able to underline any dangerousness is necessary and its necessity increases the larger the companies are. These platforms are necessary above all because they allow to have a univocal vision, thus avoiding misunderstandings or loss of important data, going to negatively affect safety, product quality, delivery, etc. If the main means of communication is manual, paper based and or verbal/informal important items can be misinterpreted, improperly prioritized, or simply missed.

Having considered the handover procedure obviously a great deal of data imparted at handover could have a considerably more extensive utilize in the event that it could be made accessible in a proper configuration. On the off chance that other individuals were to begin getting to that data it would expand the quantity of partners all the while. More individuals would have a personal stake in enhancing handovers and would probably intercede if the data they require was not inevitable. At last it appears to be likely that a superior accord would be come to over what should be imparted at move handover. The proposition here is that the log books and handover reports utilized at handover could be utilized to record data that would then be able to be shared. The magnificence of this data being that it reflects what really occurs practically speaking. Up close and personal correspondence will remain the most essential piece of the handover, however the log books and handover reports will include structure and detail.

The handover procedure can envelop an extensive variety of data including the logs of past occasions, the present plant status, and issues for future movements. This is valid for move handovers that happen every day and for 'trip handovers' that may happen week by week, month to month or considerably more. Keeping in mind the end goal to effectively support the handover procedure the arrangement must satisfy various key necessities:

- Facilitate logging of data: Whatever technique for catching operational data is utilized, it will be, to some degree, an inconvenience on the administrator. The proposed arrangement empowers quality logs by permitting most data related with a passage to be made with a couple of mouse clicks. The administrator is then required to type just esteem included data, which by and large clarifies why an occasion happened. The administrator is guided through the logging procedure structurally, guaranteeing all basic data is caught. This has included advantages for less PC proficient administrators as it limits the information required.

- Provide an organized logging condition: It is basic that any arrangement gives the adaptability to catch all the differed operational exercises required in logs over the activity. In the meantime, it is critical to force a level of structure on the logs to empower consistency of info. Essentially accommodating free-organize content section gives adaptability however does not take into account an organized approach. The arrangement permits 'Occasion Progressive systems' to be pre-characterized. Each log can have its own particular chain of command tuned to the particular logging prerequisites. Every chain of command point (an occasion that can be logged) can have its own format. This format characterizes the structure of the log passage and can suit any extra data to be caught, any guidelines on how the section is shared or duplicated with different logs and any outside reports to be joined or referenced. The level of structure forced by the format is characterized by the clients. A layout could in its least difficult frame be a straightforward free organization content field. This layout approach guarantees that a similar occasion logged after some time will be signed similarly and is of incredible advantage when looking into and providing details regarding logs.

- Allow for simple sharing of data: The arrangement permits log sections to be effortlessly shared over various logs all through the activity. This can be mechanized if required to guarantee essential data is exceptionally obvious to the proper individuals or issues are viably raised.

- Allow snappy looking and detailing of logs: The arrangement enables simple access to logs, regardless of whether it is the present move investigating the past move logs, engineers completing examination of noteworthy logs or administration announcing over various logs. Giving the organized formats enables reports to be effectively assembled. This helps divert the logs from an operational record to be documented into a live store of important data. The logs end up significant resources of the business.

A standout amongst the most imperative parts of the arrangement is the capacity for every zone to design its own particular log structures. This is a client focused arrangement that accomplishes purchase in from the client base and thusly prompts higher quality logs. This is substantially more attractive than forcing an unbending framework on administrators that does not meet their own individual or departmental prerequisites. It must be stressed that any automated answer for overseeing shift handovers can just help (and not supplant) a well thoroughly considered and very much took after handover method. The more extensive contemplations are those of organization and operational culture and teach. A culture of open correspondences, constant learning and persistent checking of process quality can be supported by an all-around created mechanized framework yet can't at last be controlled by such a framework; the entire procedure begins and end with the associations greatest resource—its kin.

In executing such an answer, it is essential to perceive that, as with any mediation in any framework, there are constantly potential negative results. For this situation there is the potential that making data all the more promptly accessible over a PC system may imply that individuals converse with each different less frequently. While it is felt the way the arrangement works implies more individuals will wind up intrigued by what is happening and consequently are in reality more prone to make inquiries and talk about occasions, this is something that should be checked as a major aspect of its execution. Likewise, it is perceived that this arrangement may not as of now be suitable in places where a huge extent of the workforce either don't approach a PC or do not have the fitting aptitudes. This arrangement has been being used with incredible accomplishment inside a few expansive activities with client bases in the 100s. One vast site in the UK has utilized it for more than three years. It supplanted numerous paper-based and singular PC based logs with a solitary, coordinated arrangement that enables operational information to be shared 24 hours per day while interfacing with other existing operational frameworks. For another situation an extensive power age and conveyance organization utilized the answer for build up a coordinated logging framework over its different scope of locales and corporate level capacities.

Following a pilot venture, the arrangement was executed over the organization in four months. And in addition commonsense advantages, for example, more predictable logs and enhanced accessibility of data, social upgrades have been experienced including administrators having a superior comprehension of the estimation of amazing logs, move handovers are significantly more productive on the grounds that the high perceivability of data empowers the approaching group to rapidly get 'up to speed' and enables them to make astute inquiries to guarantee they completely comprehend the issues.

There is almost certainly that move handover is a basic action and poor handovers have added to significant mischances. Be that as it may, it has gotten generally little consideration and the direction accessible is somewhat restricted.

The objective of move handover has been characterized as 'the exact, dependable correspondence of errand important data crosswise over move changes, in this manner guaranteeing coherence of sheltered and successful working.' To do these approaching staff need to pick up a precise comprehension of plant status with the goal that they can settle on rectify choices and starting suitable activities as required. Enhancing shift handover expects frameworks to be set up that incorporate strategies, preparing and appraisal, checking and review. Likewise, it is important to address the behavioral angles, which might be something that associations have tended to timid far from. Organized log books and handover reports can help the face-toface part of a move handover. Additionally, perceive that specific conditions, for example, continuous support and deviations from ordinary activity make higher hazard and need watchful thought amid handover. This paper proposes a way to deal with enhancing shift handover that is reciprocal to creating and enhancing the correspondence angles. It expects to make data recorded at handover a more significant asset. Studies demonstrate data about all parts of activity are regularly recorded in move logs and handover reports, including data about human mistakes, minor episodes, routine undertakings and answers for issues. This can be utilized over the business to enhance security, unwavering quality, generation, and ecological execution.

To make the data more accessible it is recommended that a PC based database arrangement is required. This goes past basically changing over log books into PC shape, and rather brings about a complete wellspring of administration data that has numerous utilizations, and additionally supporting movement handover. The upsides of this approach include:

- Important data turns out to be more noticeable;
- Better data is accessible when settling on operational and key choices;
- Time is spared in logging occasions, which means more esteem included data can be recorded;
- Information streams much better over the association;
- A full review trail is given.

A computer-based approach has numerous potential advantages, however it must be recalled that the conduct of clients will have the best impact on move handover adequacy. Any change must mirror the human components included. In any case, move handover is a basic action and ought to be a high need for any association working in a dangerous industry. Key issues include11:

- Provision of clear strategies/composed direction portraying the key data to be traded and how this ought to be done (e.g. verbal, in composing or both);
- Providing preparing and having frameworks to guarantee representatives are skilled to utilize handover techniques;
- Carrying out standard and exhaustive checking and inspecting;
- Involving representatives in the examination and change of the practices;
- Updating frameworks in light of data from occurrences and mishaps because of move handover issues and conveying this to the consideration of representatives.

After a few examinations on the best possible move handover setting, with successful instruments, it seems clear that the subtle elements of work-in-advance are not generally precise passed on amid move handover, causing that more often than not in this manner undertakings are frequently rehashed from the earliest starting point. A considerable measure of data conveyed at handover could have a substantially more extensive utilize in the event that it could be made accessible in a proper configuration, taking out what may be clear as far as loss of dawdled and material.

An effective correspondence is gotten when the administrator getting a message accomplishes the very same comprehension of that message as the one transmitting it planned, it appears to be trifling however frequently it isn't what happens. (Brazier and Pacitti, 2008)

5.3 The importance of monitoring performance over time

The business is increasingly arranged towards the need of a coordinated arrangement that enables administrators to have the capacity to share all the fundamental data, accessible 24 hours every day, on account of the operational learning that would interface be able to with other existing operational frameworks. In avionics Pilots finish a scope of both operational and security reports toward the finish of each flight. These are connected to the two tasks administration and execution/security administration exercises as a feature of an aircraft's flight activities process (Leva et al 2010). The key illustration is the Flight reports/flight log used to report rundown operational data identified with each flight. This incorporates landing pilot, surrenders recorded, residual fuel, take-off and landing times, delays and any administrations utilized. The plan of the flight log relies upon the prerequisites of the particular carrier. Most carriers have executed electronic reports open on an electronic bag or laptop computer.

Correspondingly, all the while and vitality division to control everyday hazard factors the association are outlining and executing administration frameworks, ready to economically control and regulate an intricate procedure: this could be embraced through a steady observing. Mischances like the fire and blast at a refinery in Texas City can be effectively evaded later on if an unmistakable perspective of what is occurring can be all the more effortlessly kept.

5.4 Key factors for successful handover

Various key focuses were recognized from a survey of the exploration and direction completed by the main creator as a major aspect of the Buncefield examination. This affirmed pertinent HSE direction had been promptly accessible for quite a while before the mischance, beginning in 1989 with the main release of HSGE's center human elements' direction (HSE 1999), and had been frequently utilized by the inland significant danger enterprises to create and enhance move changeover courses of action.

The key hierarchical issue supporting effective handover is that the significance and high need of dependable correspondence is formally perceived by the association and its administration, and reflected proportionately in the courses of action made for this in the security administration framework and the pertinent hazard control frameworks. Administration ought to likewise determine no less than a base period for handovers. Regularly a handover on a 12-hour move may last up to 30 minutes, however shorter periods might be adequate relying upon the multifaceted nature of the procedure or action and current status, gave the handover is all around organized and thoroughly considered. On the off chance that this requires additional time then that ought to be paid or generally remunerated.

Different methods for focusing on the significance of handover incorporate making courses of action to guarantee a sensibly continuous period is accessible for changeover i.e. time in advance to get ready and time a while later to merge/check, and intending to stay away from – or put off – key undertakings amid changeover, and limiting interferences. For instance control rooms might be secured against intrusions for that period, and telephone calls held or kept short. In an audit of one seaward organization's handover courses of action the accompanying issues were distinguished as key for good practice (Lardner 1999): . The requirement for good outline of handover logs and different records or employment helps. Utilization of reasonably composed agendas or different prompts for handovers.

Repetition and decent variety in correspondence media; two-way correspondence and criticism. Determining the time regularly expected for handovers. Investigation of data and client needs in various working modes e.g. typical, strange, start-up/shutdown, upkeep (and in view of danger/chance). Utilization of e.g. a perusing record for team changeovers or after long rest periods so new group can make up for lost time completely with what has happened in the mediating time frame. Indicating the significance of gathering handovers and additionally singular ones. Other particular measures for guaranteeing fruitful changeover incorporate the arrangement of the essential assets (counting time), and arrangement of direction and preparing for the staff included.

Various more particular cases of methods for guaranteeing that dependable exchange is additionally given in the direction. Notwithstanding the reiteration of key data in various media e.g. composed and verbal, work force included ought to effectively affirm and clear up the key data when imparting it. It is additionally imperative to limit superfluous data with the goal that the framework does not end up depreciated. At last, in recognizing key administrator bolster/helps for handover, utilize can progressively be made of electronic data – including e-logs – and show screens e.g. for control room administrators to push through both as a major aspect of giving over the plant or process and as a mistake catching activity to ensure that off base suspicions are not made by either administrator.

Mishaps, for example, Buncefiled, Texas City and the Sellafield shoreline gave cases of how poor move handover and absence of correspondence of operational data specifically can be a contributing element to significant disturbances.

Numerous organization all the while and vitality division are currently progressively perceiving the basic significance of supporting better correspondence amid the move. This significant change has been caused by both financial and administrative weights request (Wilkinson and Lardner, 2003).

5.5 The process of structuring shift handovers, what needs to be included and why.

5.5.1 Criteria to structure Electronic Shift logs

Shift handovers ought not be a copy of a DCS Log record, however only a choice of a subset of parameters as well as criteria to be watched and observed all through all movements. They are important to give a rundown perspective of the framework and in the meantime to guarantee a consistent and exact checking of the principle parameters, getting a vital bulletin. There is no compelling reason to copy on such a stage every one of the cautions setting, as it could cause data over-burden and duplication of unessential data. There ought to be a help to screen certain parameters to demonstrate a decent or bed running conditions for a plant inside expected execution parameters, and solicit toward the end from each move the administrator to report about what is occurring and why. What are the criteria to help the choice of the key data to be observed and detailed about in an e-log for each shift?

5.5.2 The necessity of a structured approach to shift handover

A few examinations have shown that around 80% of modern activities do not have an organized way to deal with move handovers. Because of late move handover explore we can watch how an incorporated agenda and logbook to structure the move handover, rather than a less organized logbook, can impressively build the move handover viability. (Thompson and Plocher, 2011) The Move Log might contain adequate detail in a precise, succinct and clear arrangement to help the full comprehension of every noteworthy occasion.

5.6 The shift log, what process to follow

As per the examination directed by Thompson and Plocher (2011) each move should record the accompanying points of interest:

1. Basic data: date and move, plant distinguishing proof and creator's name.
2. Safety data: every episode/close miss occasion indentified has a report with his fundamental data. A startling occasion could cause the plant exchanging. Augmentations or evacuations of transitory plant alterations, control framework reenactments and/or supersedes ought to be recorded.
3. Environmental Data: occasions affecting the natural execution should be reported so as to maintain a strategic distance from disappointments/mishaps influencing condition and decreasing danger of neglecting some basic parameters.
4. Plant data: status, execution outline and work orders raised could recognize accurately and in time any signs requiring dire activity, and characterize the outcomes for assessment arranging.

5.6.1 Safety information

The greater part of the occurrence/occasion or disappointment are gathered in the Move Handover Board, with the goal that they can be effectively counseled, giving a moment outline of what should be done, and in view of the advanced menu, reports are clear and deciphered consistently. All the changing occasions should be accounted for, e.g. plant changing because of a surprising status or non-standard/uncommon sustaining or working courses of action must be chosen, so anybody of the plant task group can access and view to the data/information. All the data and security archives are required where the area has an introduced Electronic Allowing Framework. In the event that there is an upkeep stage in advance for working or generally the segregation of a wellbeing framework must be recorded, as this is a basic parameter for the plant.

Other information that should be accounted for in a move log ought to be the augmentations or expulsions of transitory plant alterations, control framework reproductions and/or abrogates, to record nitty gritty reports valuable to oversee and assess plant changes.

5.6.2 Environmental Information

In the event that effectively actualized, tremendous advantages can be acquired from the move datasheet, including end of identifiable wellbeing and natural risks. The important point of utilizing the move log is simply decreasing danger of disregarding some basic parameters, as the arrangement enables simple access to logs, regardless of whether it is the present move looking into the past move logs, engineers completing investigation of notable logs or administration revealing over various logs. This layout approach guarantees that a similar occasion logged after some time will be signed similarly.

Understanding what remarks and perceptions have been recorded about ecological utmost surpassed or issues for a specific unit shows signs of improvement information's consistence, so as to keep away from the dirt, air and water sullying. Crisis shutdown Frameworks or alleviation frameworks avoided or blocked, caution setting changed ought to be recorded. This perspective can obviously be supported by a more watchful examination and grouping of information, without absence of structure.

5.6.3 Plant Information

The shift log can indicate how the plant is delivering, in the event that it is increase or down, a view to day by day operational site, when it is on-load or it is in shutdown. At the point when an excursion, or an episode/close miss occasion is recognized, a report with the fundamental data is suffocate up, trailed by examination and execution guidelines, sited in the direction list see board, accordingly, in the wake of being approved, the information are distributed on the dashboard, so the embraced plant arrangements fill in for instance for future occasions. All the plant execution are appeared, handover formats give an approach to control the look and feel of Handover Reports. The criteria for choosing what to screen could depend from the First Gear Maker security circuit, all the farthest point and changes, all the science (testing, dosing) or mechanical esteems depend on the norms. Modern research has contended for the advantages of forcing structure on move handovers as organized logs, agendas, and presentations.

An organized way to deal with move handover enhances circumstance mindfulness among activities faculty at process plants. This should ensure a counter framework that tracks how regularly an esteem is hitting alert points of confinement yet in the meantime, there is no requiring of rehashing excessively information, just an observable change in an esteem ought to be accounted for.

To address this inquiry, it's valuable to investigate the field of observing of hardware for support purposes. To satisfy the new desires and market request, upkeep programs have been in certainty developing, getting the right hardware task and its capacity at any rate consumption of assets. Condition based upkeep (CBM) is a standout amongst the most beneficial administration logic used to settle on choice about support or repairing/substitution on the present or future state of advantages. (Prabhakar and Raj, 2014) This technique centers around whatever could trade off key plant operational wellbeing, and its assignments are basically performed to decide whether an issue exists in a gear, how genuine the issue could be and to what extent the hardware can keep running before disappointment or to recognize and distinguish particular segments in the hardware that are corrupting and to decide the underlying driver of the issue.

Condition-observing strategies can be characterized by the sort of side effects they are intended to distinguish. The orders are as per the following:

1. dynamic impacts, for example, vibration and clamor levels;
2. particles discharged into the earth;
3. physical impacts, for example, splits, cracks, wear and misshapening;
4. temperature ascent in the hardware;
5. electrical impacts, for example, protection, conductivity, dielectric quality, and so forth. (Tsang, 1995)

CBM methodologies can offer an extremely very much organized arrangement of criteria to choose what to search for when checking key basic segments every day.

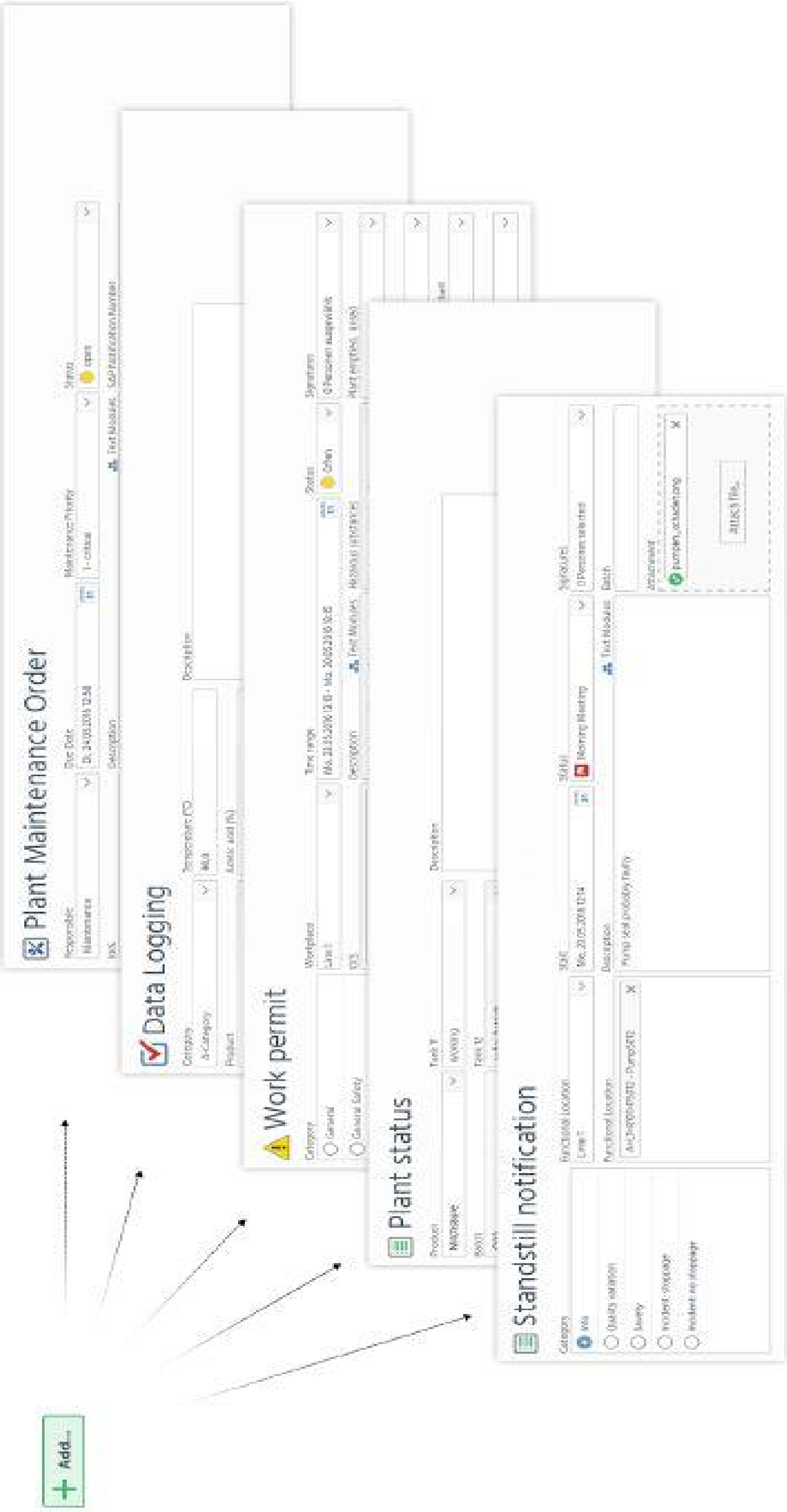


Figure 24 - The shift log Design

6. Shift handovers for aging equipment suggestions for inclusions

For control framework administrators, all segment upkeep arrangements must be put into framework setting. The objectives are to boost framework unwavering quality or limit framework working expenses. Here is the significance of utilizing shift handover adequately, as it tends to postpone a successful support process guaranteeing that the execution of the framework is ensured. When managing maturing hardware the working states of the gear is a key factor that can help ensure a more extended life cycle for maturing parts and abstain from quickening maturing flow.

6.1 The limit between what is profitable against the market demand

The activity of ordinary fossil ages is unequivocally changing because of the effect of virus and the expansion in the entrance of inexhaustible variable ages. (Kumar et al. 2012) To remain focused, utilities need to better comprehend the basic idea of their plant activities and support expenses, and take measures to utilize this learning further bolstering their good fortune. Market request and charge of prerequisite anticipate that maturing plants will cycle all the more regularly. Each time a power plant is killed and on, the kettle, steam lines, turbine, and assistant segments experience unavoidably huge warm and weight stresses, which cause long haul, unsalvageable and auxiliary harm. This harm is exacerbated for high temperature parts by the marvel we call crawl weakness association. This causes a disappointment of basic parts in the plant, despite the fact that cycling-related increments in disappointment rates may not be instantly taken note.

In view of cycling efficiencies more seasoned joined cycle units were a stage change in bring down working expenses and were composed and worked as baseload units, without a doubt these consolidated cycle units can have higher cycling costs contrasted with a unit particularly intended for cycling and this occasion can be seen from the appropriation of expenses. The majority of this is mostly caused by changing markets have brought about factor task and when worked in cycling mode. (Kumar et al. 2012) Cycling task builds the worry for crawl weariness harm caused by warm anxieties, particularly in units intended for baseload activity. Crawl exhaustion is a prevailing disappointment mode for harm and disappointments of numerous fossil plant segments. Its harm as a rule happens as a result of warm worry in compelled segments amid warm homeless people. For gas turbines, the effects of startup, shutdown, and part stack cyclic activity on the segment life, upkeep cost, emanation consistence, unit unwavering quality and accessibility are critical.

6.2 What type of data and equipment is critical to include in structured shift handovers for aging plants? An example for a coal power plant

Around 60% to 80% of all power plant disappointments are identified with cycling tasks. A study of 215 steam plants discovered numerous normal gear issues: the most successive is warm pressure, trailed by consumption and water enlistment, different issues are hub relocation, vibration wear, outward pressure and fast cooldown. (Hesler, 2011)

Consequently, in an electronic Log it's essential to have a Transient Report, that can demonstrate every one of the information significant for the hardware influenced by cycling: it can demonstrate the need to screen cycled and transient condition and plant condition execution.

There are three diverse low load cycling focuses: the first is the least load at which plan temperatures can be kept up, the second one incorporates current publicized low load and the third one is the most minimal load at which the unit can stay on-line. After these three low levels there are three on/off cycles, that are characterized in light of hours disconnected, with the most exceedingly awful harm happening amid a chilly begin cycle. While for hot begin the plant can be disconnected for 1 to 23 hours, the warm begin is after the plant has been disconnected in the vicinity of 24 and 72 hours while the icy begin happens after the plant is over 72 hours disconnected. Load following situations have generally low harm costs but since there are such a significant number of them, the combined effect of numerous heap following tasks prompts the harm of an identical hot begin. It is critical to perceive, check and arrange all these minor load-following activities, till considering the heap take after down, there is the base load for a plat, after which the shutdown of the plant is normal. The initial step to deciding working expense is to look at the real approved plant support expenses and include the evaluated cycling harm cost.

Once the information on the expenses of cycling are inspected and the requirement for a point by point money related model has been by and large characterized, a rundown of particular segments that are ordinarily unfavorably influenced by cycling in the vitality division and their essential harm systems can be delineated.

In a little and expansive sub-basic coal unit the primary thing destined to demonstrate antagonistic effects from cycling is the heater and its particular segments. The kettle headers for example are influenced by exhaustion and consumption weariness because of blackouts oxygen and high begins up or compound store. The heater Superheaters and Reheaters are influenced by high temperature differential and problem areas from low steam streams amid startup, prompting long haul overheating disappointments. The economizer is influenced by temperature transient amid new businesses. The Low-Weight turbines are ordinarily influenced by sharp edge disintegration. Now and again the Feedwater Warmers are influenced by cycling costs, since they are not intended for fast warm changes. Icy and bushel consumption at low loads and at start-up are the essential harm instruments for the Air Warmers; likewise, Water Treatment is influenced by cycling, particularly in top requests on condensate supply and oxygen control. The Fuel Framework or the Pulverizers are influenced by cycling of the plants, that can happen even just from stack following task as iron wear rates increment from low coal stream amid swing down to least.

Unmistakably if these parameters are relentlessly observed, everyday plant execution could be enhanced, and a superior working condition can be deliberately looked to restrain the harm caused by maturing and to defer support, or if nothing else to characterize upkeep and load necessity for the hardware in light of its status and not on what is normally done in the plants.

A fast-main drivers examination was led in an Irish power providing organization, assessing their operational dangers enroll intermittent reports. The hazard situations distinguished were adapted, concentrating just on the dangers that had a predetermined reason identified with plant maturing. Plant age as well as working conditions was featured as the most well-known main driver representing around 45% of the adapted hazard introduction revealed in the hazard enroll, detailed in the following table.

Root causes analysis	Monetized Risk Exposure (€)	Percentage
Aging	21.848.398,70	45%
Organization & Management Deficiencies	7.531.979,10	16%
Others	18.975.778,60	39%
Total	**48.356.156,40**	100%

Table 25 - Root causes analysis of risks related to aging equipment in an Irish company

Going to a more detailed analysis and evaluating also what are the primary aging causes it can be stated that the Monetised Risk Exposure is about 13.726.525,80 €, therefore the root causes associated with aging equipment are 63% primary.

6.3 The benefits and the advantages using the digitised and structured shift handover: case study

To reasonably control complex procedures, the administrators responsible for everyday activities need to get undertaking backing and checking limit over day by day execution. The likelihood to digitize move handovers could help guarantee a superior outline and checking in plant activities. On account of the program, each move can do produce an execution month to month report, with security execution or consistence scorecard and episode reports. Every one of the information are changed over in forbidden networks, line diagrams, or pie outlines. This permits to oversee and have a thorough perspective of the plant for a somewhat drawn out time, keeping in mind the end goal to feature any inadequacies or necessities, so execute them to continually enhance the yields of the plant itself. The objective is to streamline support and amplify accessibility.

This extra module can set execution targets and demonstrate the general gear influencing the objectives concentrating on plant proficiency, breaking down accessibility, run time, operational time and beneficial hours. Thusly, a perspective of plant proficiency is ensured over some stretch of time and how these qualities move far from the objective set; the information investigation is graphically bolstered and all records can be effortlessly accessible. This enables the task supervisor to recognize and wipe out the reason for misfortunes.

The investigation exhibited in this thesis endeavors to address the hole in direction on development of digitized move handover by depicting the consequences of a contextual analysis that featured the need of the stage and how its action can advance the plant execution. One of the foremost issues that happen in the stage setting is the absence of information investigation, which is a basic component for its ideal utilize. Understanding which are the primary trek, or the most widely recognized ones, what standpoint are they maintaining, which hardware is included the most, and what working conditions ought to be stayed away from by the administrators are key inquiries that when tended to legitimately can truly enhance plant execution.

With a specific end goal to legitimize such proclamations a specialized outline and information examination is connected on a contextual investigation in a power age organization over numerous area in the Republic of Ireland. This examination means to feature the alerts and treks that were recorded when the main sending of the operational logs, as can be shown in Figure 26.

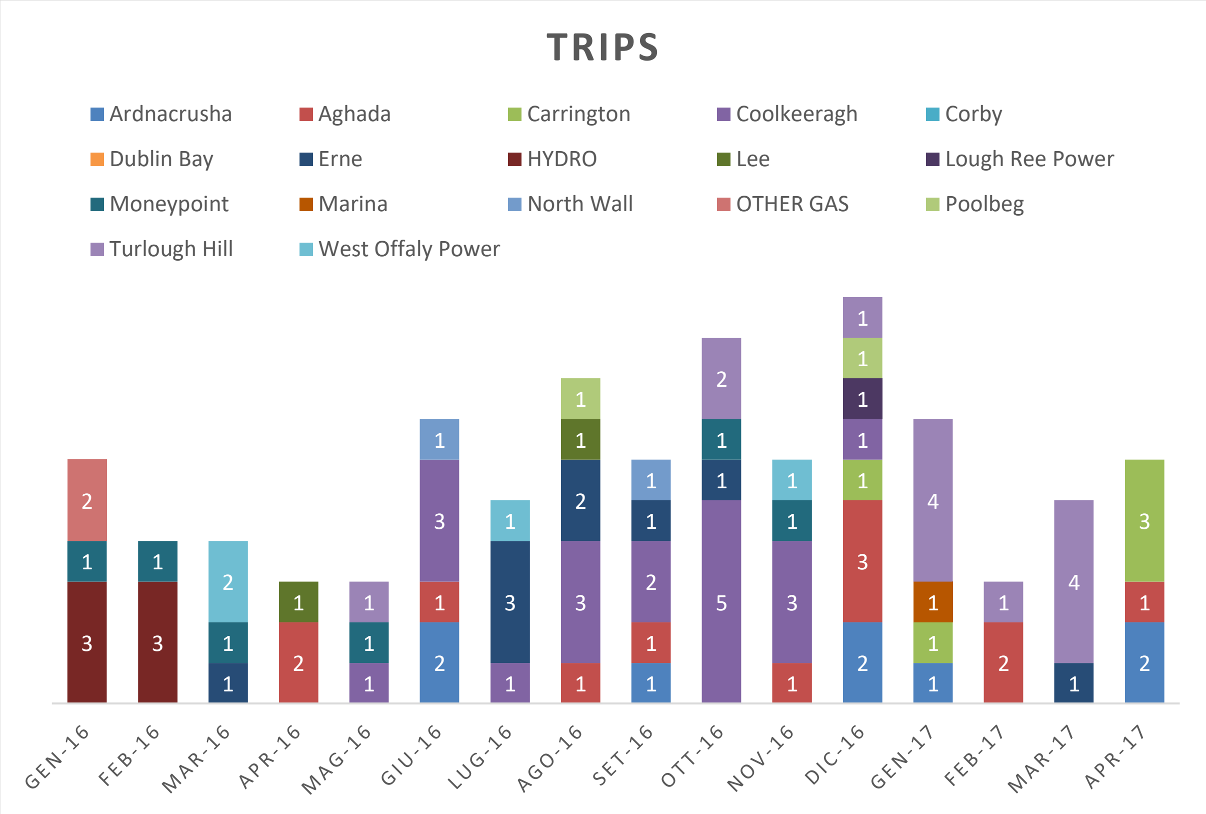


Figure 26 - Signals and trips analysis in an electricity generation company

The shift log initial deployment started in April 2016. The immediate effect of the shift log was an increase in the level of details and the information collected around trips, as can be seen these are the numbers of high level alarm and trips occurred during that period. The one going from June to November 2016 coincides with the period were overhaul works and projects are running in all the stations therefore it is normally associated with an increase in the number of trips associated with the plants. However, starting from January 2017, the number of trips decreased considerably while maintaining a higher degree of information and control on trips causes and related issues on a day-to-day basis. The different colors in this figure are related to the different stations identified. Finally, the various trips are shown inside the individual stations, highlighting their dangerousness

Alarms & Trips

2016						2017			
July	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**
Unit trip from vibration panel	EHF Card Failure	Roof leaking above unit as a safety precaution unit was taken off load.	Governor 220v DC MCB trip, governor solenoid	Failed to Synch. due to Turbine LP Bypass problem.	Transformer trip	REF Trip (ROTOR EARTH FAULT)	on behalf of SM - CTD thermocouples, only 2 of 4 operational	Static Starting Device TRIPPING ON RUN UP	Trip caused by high hotwell level, failure of feedwater tank level control
Unit tripped on shaft seal temperature	Unit Failed To Synch At 08.00 am. Late Sync @ 15.59 pm 23/08/2016. Diesel Oil Burners failure & Drum level trip.	failed to synch - GT Controller Flt	B end trip CPD differential HiHi	Maintenance attempted on IBH valve	AA3 trip on governor fault (REPLACED 5V POWER CARD)	Control system fault. 5th Electrode tuning fork fault.	Failed mobrey switch on turbine	SSD CB will not close	Tripped Following Sync - HP Stress Limiter issue - Sync @ 09.28.
Trip on shaft seal high temperature	ST PROBLEM	Unit high temperature trip	unit trip, differential	Unit 1 Trip: On High Drum Level.	Steam leak	Control system fault. 5th Electrode tuning fork went into fault.	Fail min - air inlet compartment door trouble	5th electrode trip	Unit Fail Sync. HP stress limiter - Sync @ 09.28.
Unit tripped turbine lube oil pressure	Unit Failed sync. Voltage issue sync panel and avr.	Excitation Failure - Trip	Late Sync Due To Coal / Burner Issues. Sync @ 15.16.	trip during within day test	Control Oil Issues. SRV trip oil pressure low.	Control system fault. 5th Electrode tuning fork fault	Fail Sync - Unit 1 - Mill Issues	5th electrode trip	Unit failed to sync (UNIT 4 WAS AVAILABLE & THE LATE START IS DOWN TO HCC)
MAINTENANCE on recent vibration issues	Tripped on shaft seal temperature	Unit trip. High atomising air temperature	unit tripped from external trip to protection panel.	Generator air intake high dp	Plant would not start. Problem traced to GT Mark VI flame	Control system fault. 5th Electrode tuning fork fault	Fail Sync - associated with air inlet compartment door trouble	5th Electrode trip	GT PLS from HRSG - Spurious Trip

					on signal to DCS relay failure. Card replaced.				
	Unit 2 tripped on high shaft seal temperature. Zebra mussels block cooling water line.	Unit failed to sync. Master protective relay trip prevented start.	Unit Trip On ID Fan Duct Suction Pressure On Raising Load.	UNIT TRIP Low lube oil pressure	Turbine Guide Bearing Level Transducer Failed.	Leak at HP oil gauge	failsync - decl moved back 1 min (DUE TO LOW OIL LEVELS IN THE TURBINE BEARING)	Spurious trip from lower guide bearing s-max reading	Unit tripped on run up (ELECTRICAL FAULT ON TRANSFORMER T102)
	220V DC Protection MCB trip	Fail Sync 14:15. Sync @ 14.38.	B End Trip - B Avon tripped on high vibration during start.	MIV fault	Failed to ignite. Cable to ignitor required replacement.	GT tripped on run-up due to TAT t/c trouble.		Unit Failed To Synch. HP Stress. Sync @ 06.58.	As Per Fail Sync Process - HP Stresses.
	GT8 TRIP ON START-UP	Loss of A End - High exhaust spreads	REVISED AVAILABILITY FOLLOWING B END TRIP due to high engine vibrations	Trip on fuel change over - SRV low trip oil pressure trip	gas turbine trip due to EHF (Control / Protection Stystem) failure	Fail Sync. Trip Devices Issues.		Fail Sync. Unit Sync @ 02.26 AM on 11-03-2017.	
	Steamer tripped - tripped when changing oil pumps to test stand-by	Trip on A End on Start-up - exhaust temperature spread	FT - B-End Avon b high vibration during start.		governor fault			mobrey switch fault	

6.4 The link between digitized shift handover /operational Log and the company risk register

As a major aspect of the procedure wellbeing change design of the organization there is an on-going push to help reliable and productive exchange of security, operational and business data between the operational movements and the hazard enlist. This exertion intends to diminish the potential for misconception or the non-detailing of specialized or business occasions identified with known dangers the organization wished to keep under close observing conditions and the likelihood to progressively refresh those dangers by looking into issues rising up out of intermittent operational setbacks or conceivable early cautioning because of challenges in keeping operational conditions inside required limits. In the digitized move handover in truth the log will require recording of operational variations from the norm including: request on wellbeing frameworks, plant upsets, lacking working control, systems not took after, close misses, and so forth as lower level episodes, which can be then be investigated and enhanced. This can likewise fit a method for enhancing a two-way live nourish between an operational log and the hazard enlist as the hazard enlist can give an outline of the fundamental organization chance situations important for activities yet on the opposite end the operational log can give information to confirm how those dangers may really influence operational practices and present new potential dangers based on watched deviations from prescribed plan ranges.

An example of the info exchange between the risk register and the operational log, focusing specifically on risks related to aging equipment is reported in Figure 25.

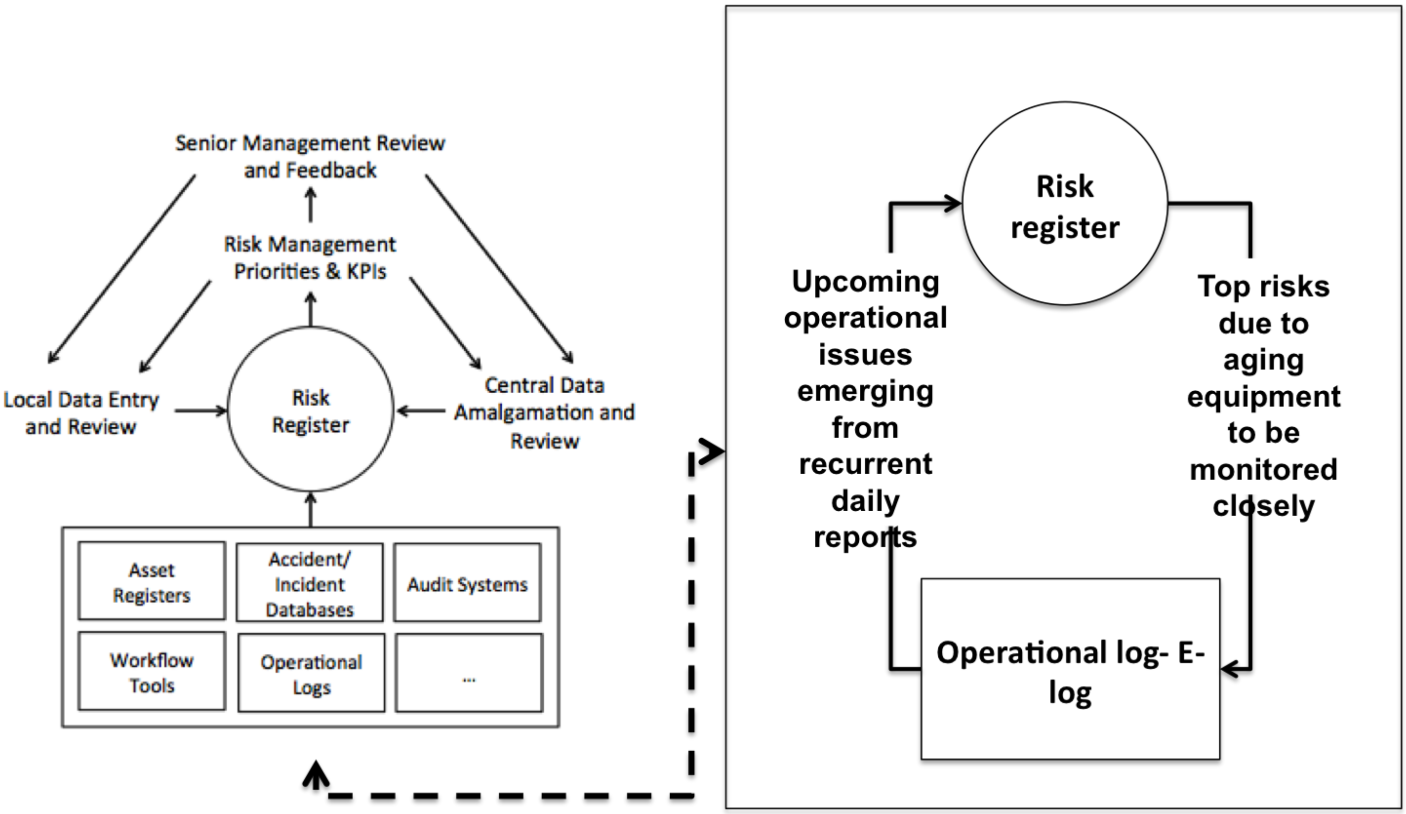


Figure 27 - Link between the company risk register and the operational log/ shift handover system

7. Conclusions and way forward

The need to quickly create novel robotization originals and the expanded multifaceted nature of communicating frameworks of frameworks in todays' procedure plants has expanded the measure of information activities director should have the capacity to deal with to have an entire diagram of real plant execution, particularly about wellbeing basic situations, which are not generally all around announced.

The best possible utilize and structure of move handover can catch and make information available over all the mechanical association. Improving the viability of the operational log could be picked up by giving a sound structure to administrator logging, in light of key classes of situational data. (Plocher, et al. 2011)

The last phase of any administration framework is ceaseless audit. This ought to incorporate proactive and receptive intercessions. For this situation the point is to keep the yield from the procedure up and coming, and search for chances to enhance the general frameworks. One thing we should stress is that the aftereffect of audit is constantly to distinguish obvious holes that should be loaded with more errand examinations, techniques and so on. This is one reason why organizations have such issues with their frameworks constantly developing. Staying with the standards of Assignment Hazard Administration can help maintain a strategic distance from these 'automatic responses. The most ideal method for ensuring any framework is filling in as expected is to utilize it. In the event that an Errand Hazard Administration is actualized as depicted above you will have created methods, preparing and capability frameworks. On the off chance that these are utilized as proposed, data will be consistently accessible about how well these frameworks are functioning.

Similarly as with all frameworks, it can't be accepted that the yield from Errand Hazard Administration will be right for eternity. Thusly, survey and review is critical; and should take a gander at the entire framework (i.e. undertaking records, prioritization, errand investigation) and the individual assignments.

Choosing what level of survey and review can enable you to choose what number of assignments you investigate in any case. Sooner or later you will find that the exertion put into breaking down lower criticality assignments would be more advantageous in the event that it was coordinated to checking on the higher criticality errands that have just been broke down.

It is genuinely evident that any episodes or mishaps that happen should bring about a survey of important methodology, preparing and capability frameworks. Be that as it may, I trust that having actualized Assignment Hazard Administration will enable you to explore the reason for occasions all the more adequately when they occur later on. For instance, noting the accompanying inquiries will enable you to recognize foundational and underlying drivers:

- Was an undertaking being done that was not on the tasklist for the framework?
- Had the undertaking scored low in prioritization, yet been associated with a huge episode? Was the errand being performed in the same was as portrayed in its HTA?
- Had the mistakes that happened in the occurrence been distinguished in the Errand HAZOP?
- Were the current hazard control measures distinguished in the appraisal right and powerful?
- Had proposals for enhanced hazard control estimated been actualized?

This receptive component demonstrates why Assignment Hazard Administration is much more than basic errand investigation.

Numerous key advantages result from an organized move handover arrangement, for example, the followings:

- The capacity to rapidly discover pertinent data, enhancing shift handover correspondence;
- Saved time as far as catching information/more prominent data and pulling them together for the move rundown report;
- Improved technique to get to quicker and with precise strategies to recorded data, with a rundown of classes, every one of the reports are effortlessly found;
- Improved unwavering quality/lessened downtime; improved and quick correspondences of choices over all associations at the site, not simply activities;
- Improved administrative consistence (where material) given computerized recording and documenting of reports in an organization that isn't editable;
- Improved cross office correspondence, sequential history perspective of status of the undertakings;
- Consistent situational mindfulness for all clients; and enhanced information for process change exercises and occurrence legal sciences.

There is existing exploration and direction on great practice for move handover correspondence however more endeavors are as yet required in the territory of really utilizing operational information to increase better hazard knowledge on everyday administrator's assignments and how to improve activities for maturing plants. In the vitality segment specifically, this could end up being a key upper hand as maturing plants are relied upon to cycle all the more habitually and along these lines the satisfactory worry for activity required from showcase request should be relentlessly controlled.

Subsequently the requirement for a day by day assignment bolster for administrator can offer the chance to help correspondence among shifts and a superior observing of the working conditions forced on maturing gear and their basic parameters. Maturing plants at times should work more than their ability, so it's smarter to center around the working information and utilize them to dodge disastrous disappointments. The objective is to locate the great harmony between what it's gainful against the market request and guaranteeing great practice regarding security for ordinary tasks.

PAPER Abstract

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Cost benefit evaluation of maintenance options for aging equipment using monetised risk values: a practical application

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Abstract

With constant pressure to reduce maintenance costs as well as short-term budget constraints in a changing market environment, asset managers are compelled to continue operating aging assets while deferring maintenance and investment. The scope of the paper is to get an overview of the methods used to evaluate risks and opportunities for deferred maintenance interventions on aging equipment, and underline the importance to include monetised risk considerations and timeline considerations, to evaluate different scenarios connected with the possible options. Monetised risk values offer the opportunity to support risk-based decision-making using the data collected from the field. The paper presents examples of two different methods and their practical applicability in two case studies in the energy sector for a company managing power stations. The use of the existing and the new proposed solutions are discussed on the basis of their applicability to the concrete examples

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Keywords: Cost benefit evaluation, monetised risk values,

References

1. Mc Nett W., Deferred maintenance and risk assessment: Technical analysis is critical to the process, 2016, available on line at: http://www.plantengineering.com/single-article/deferred-maintenance-and-risk-assessment-technical-analysis-is-critical-to-the-process/ae7fd166735e91e4d9b405aeae82355f.html [last accessed 08/07/2017].
2. Darabnia, B., Demichela, M. (2013a). Data field for decision making in maintenance optimization: An opportunity for energy saving. Chemical Engineering Transactions, 33, 367-372.
3. Darabnia, B., Demichela, M. (2013b). Maintenance an opportunity for energy saving. Chemical Engineering Transactions, 32, 259-264.
4. ISO 55001:2014, Asset management — Management systems — Requirements
5. ISO 55002:2014, Asset management — Management systems — Guidelines on the application of ISO 55001
6. Demichela, M., Pirani, R., Leva, M.C., (2014). Human factor analysis embedded in risk assessment of industrial machines: Effects on the safety integrity level. International Journal of Performability Engineering, 10 (5), 487-496.
7. H. R. Millwater, Y.-T. Wu, (1993). Computational Structural Reliability Analysis of a turbine blade.In: Proceedings of the international gas turbine and aeroengine congress and exposition, Cincinnati, OH, 24–27 May 1993
8. Clementel, S., & Galvagni, R. (1984). The use of the event tree in the design of nuclear power plants. Environment international , 10 (5), 377-382.
9. Galvagni, R., & Clementel, S. (1989). Risk analysis as an instrument of design. In C. Maurizio, & N. Antonio, Safety design criteria for industrial plants (Vol. 1). Boca Raton: CRC.
10. Gerbec, M., Baldissone, G., & Demichela, M. (2016). Design of procedures for rare, new or complex processes: Part 2 – Comparative risk assessment and CEA of the case study. Safety science , In press, doi: http://dx.doi.org/10.1016/j.ssci.2016.10.015
11. Baldissone, G., Demichela, M. Camuncoli, G., Comberti, L., (2017). Formaldehyde production plant modification: Risk based decision making. Chemical Engineering Transactions, 57, 703-708.
12. Baldissone, G., Cavaglià, G., Demichela, M., (2014). Are intensified processes safer and more reliable than traditional processes? an emblematic case study. Chemical Engineering Transactions, 36, 415-420
13. Baldissone, G., Fissore, D., & Demichela, M. (2016). Catalytic after-treatment of lean VOC–air streams: Process intensification vs. plant reliability. Process Safety and Environmental Protection , 100, 208-219.

14. Demichela, M., (2014). Integrated dynamic decision analysis: A method for PSA in dynamic process system, In Safety, Reliability and Risk Analysis: Beyond the Horizon - Proceedings of the European Safety and Reliability Conference, ESREL 2013, 1969-1975
15. Shift Handover After Buncefield, 2003, Chemical Engineering Transactions, Vol 31, available on line at : http://www.keilcentre.co.uk/media/1059/After-Buncefield-Handover-Paper-April-2013.pdf [last accessed 12/06/2017]
16. HSE 2011, Buncefield: Why did it happen?. Designed and published by the Health and Safety Executive on behalf of the 36 of 36 pages Competent Authority for the Control of Major Accident Hazards 02/11 available on line at http://www.hse.gov.uk/comah/buncefield/buncefield-report.pdf [last accessed 12/06/2017]
17. CSB Investigation Report Report No. 2005-04-I-Tx Refinery Explosion And Fire, 2007, available on line at: http://www.csb.gov/assets/1/19/CSBFinalReportBP.pdf [last accessed 12/06/2017]
18. Leva M.C., Cahill J., Kay A., Losa G., McDonald N. 2010. The advancement of a new human factors report – 'The Unique Report' - Facilitating flight crew auditing of performance/operations, as part of an Airline's Safety Management System. Ergonomics 53(2), 164-183
19. Leva M.C., Balfe N., McAleer B., Rocke M. 2017, Risk Registers: Structuring Data Collection to Develop Risk Intelligence
20. SYMPOSIUM SERIES NO 159 HAZARDS 24 © IChemE 1 Shift Handover – Where are we now? Jim Ross, Principal Consultant, Infotechnics Ltd, available on line at: http://www.icheme.org/~/media/Documents/Subject%20Groups/Safety_Loss_Prevention/Hazards%20Archive/XXIV/XXIV-Paper-11.pdf [last accessed 12/06/2017]
21. Symposium Series NO. 154 © 2008 IChemE Improving Shift Handover And Maximising Its Value To The Business Andrew Brazier1 and Brian Pacitti2, available on line at: https://www.icheme.org/communities/subject_groups/safety%20and%20loss%20prevention/resources/hazards%20archive/~/media/Documents/Subject%20Groups/Safety_Loss_Prevention/Hazards%20Archive/XX/XX-Paper-48.pdf [last accessed 12/06/2017]
22. Exelon Ensures Nuclear Power Plant Safety Using Online Monitoring, Exelon® Corporation, 2014 available on line at: http://www.osisoft.com/corporate/power-cbm/assets/CB_Exelon_LT_EN_FINAL.pdf [last accessed 12/06/2017]
23. Deepak Prabhakar P., Dr. Jagathy Raj V.P. CBM, TPM, RCM and A-RCM - A Qualitative Comparison of Maintenance Management Strategies, IJMBS Vol. 4, Issue 3, July - Sept 2014.
24. Albert H.C. Tsang, Condition- based maintenance: tools and decision making, 1995.
25. Brian Thompson, Engen Petroleum, Ltd., and Tom Plocher, Honeywell ACS Laboratories, Structured Approach to Shift Handover Improves Situation Awareness, 2011.
26. *Steven A Lefton, Phil Besuner*, The Cost Of Cycling Coal Fired Power Plants, 2006

27. Steve Hesler, Mitigating the Effects of Flexible Operation on Coal-Fired Power Plants, 2011
28. N. Kumar, P. Besuner, S. Lefton, D. Agan, and D. Hilleman, Power Plant Cycling Costs, 2012
29. Plocher, T., Shanqing Y., Laberge, J., Thompson, B., Telner, J., “Effective Shift Handover,” Engineering Psychology and Cognitive Ergonomics. Web. 2011.
30. Probabilistic Structural Analysis Methods for Select Space Propulsion System Components (PSAM), 2nd-6th Annual Reports, NASA Contractor Report Nos. 187196, 187197, 187198,187199,187200.
31. Cruse, T. A., Chamis, C. C., and Millwater, H. R., "An Overview of the NASA (LeRC) - SwRI Probabilistic Structural Analysis (PSAM) Program," Proceedings 5th International Conference on Structural Safety and Reliability (ICOSSAR), San Francisco, CA, August 7-11, 1989.
32. Millwater, H. R. Wu, Y.-T., Dias, J. B., McClung, R. C., Raveendra, S. T., and Thacker, B. H., "The NESSUS Software System for Probabilistic Structural Analysis," Proceedings 5th International Conference on Structural Safety and Reliability (ICOSSAR), San Francisco, CA, August 7-11, 1989.
33. Millwater, H., Wu, Y.-T., Torng, T., Thacker, B., Riha, D. and Leung, C.-P., "Recent Development of the NESSUS Probabilistic Structural Analysis Computer Program," 33rd SDM Structures, Structural Dynamics, and Materials Conference, Dallas, TX, April 13-15, 1992.
34. Ang., A. H., and Tang, W. H., Probability Concepts I Engineering Planning and Design. Vol. II Decision. Risk and Reliability, New York, Hohn Wiley & Sons, Inc., 1984.
35. Madsen, H. 0., Krenk, S., and Lind, N. C., Methods of Structural Safety, Englewood Cliffs, New Jersey, Prentice Hall, Inc., 1986.
36. Wu, Y.-T., Millwater, H. R., and Cruse, T. A., "An Advanced Probabilistic Structural Analysis Method for Implicit Performance Functions," *AIAA Journal,* Vol. 28, No. 9, pp. 1663-1669, September 1990.
37. Wu, Y.-T., "An Adaptive Importance Sampling Method for Structural System Reliability Analysis," AD-Vol. 28, ASME, Presented at the 1992 ASME Winter Annual Meeting, November 1992.
38. Dias, J., Nagtegaal, J., and Nakazawa, S., "Iterative Perturbation Algorithms in Probabilistic Finite Element Analysis, Computational Mechanics of Reliability Analysis, W. K. Liu and T. Belytschko (eds.), Elmepress International, Ch. 9,1989.
39. V. Legat, Management and maintenance engineering. Praha: Professional Publishing, 2013. ISBN 978-80-7431-119-2.
40. D. Sherwin, A review of overall models for maintenance management. Journal of Quality in Maintenance Engineering, 2000, 6(3), 138–164. doi:10.1108/13552510010341171.
41. H. Opocenska and M. Hammer. Contribution to maintenance issues in company practice. MM Science Journal, 2015, 12, 748-755. ISSN: 1805- 0476. doi: 10.17973/MMSJ.2015_12_201555.

42. CSN EN 60300-3-11. Dependability management - Part 3-11: Application guide – Reliability centred maintenance. Praha: Czech office for standards, metrology and testing, 2010.
43. V. Legat and Z. Ales. Maintainability, maintenance supportability and policy. Materials of the 58th meeting of the Expert Group on reliability, Praha, 2014. Available from: http://www.csq.cz/fileadmin/user_upload/Spolkova_cinnost/Odborne_skupiny/Spolehlivost/Sborniky/sbornik58.pdf.
44. J. Famfulik. Theory of maintenance. Ostrava: Editorial Centre VSB-TUO, 2007. ISBN 978-80-248-1509-1.
45. F. Vdolecek. Automa: magazine for automation and control engineering [online]. 2008, 5, 30-32 [cit. 2016-05-04]. Available from: http://automa.cz/index.php?id_document=37313.
46. P. Nemecek. Proactive maintenance. [online]. [cit. 2016-06-26]. Available from: http://www.kvm.tul.cz/getFile/id:1850.
47. Y. Turygin, D. Maga and N. Faitova. Building of a Flexible (Adaptive) Structure for Mechatronic System's Repair Cycle. Proceedings of 13th International Symposium on Mechatronics. Trencin: TnUAD, 2010. 112-114. ISBN 978-80-8075-457-0.
48. J. Krivohlavy, Technical diagnostics, 2016 [online]. [cit. 2016-07-1]. Available from: http://jan.krivohlavy.cz/Technicka+diagnostika.
49. M. Hammer. Technical diagnostics: Materials for study. Faculty of Mechanical Engineering, Brno University of technology. Institute of Production Machines, Systems and Robotics, 2015.
50. F. Helebrant and J. Ziegler. Technical diagnostics and reliability II. Vibrodiagnostics. Ostrava: VSB – Technical University of Ostrava, 2004. ISBN 80-248-0650-9.
51. R. Jankovych, M. Hammer, A. Turygin, M. Zhalo and V. Veselkov. Vibration Condition Monitoring in 21st Century. Faculty of Mechanical Engineering, Brno University of technology, 2015.
52. Team 2016. A Project under the specific research at the Faculty of Mechanical Engineering, Brno University of technology.
53. SKF. Analysis and Reporting Manager Software, 2014.
54. V.S. Viswanath Dhanisetty, W.J.C. Verhagen, Richard Curran. 2017. Multi-criteria weighted decision making for operational maintenance processes. Journal of Air Transport Management
55. KusumawardhaniMayang, Mayang Kusumawardhani, GundersenStåle, Ståle Gundersen, ToreMarkeset, Markeset Tore. 2017. Mapping the research approach of asset management studies in the petroleum industry. Journal of Quality in Maintenance Engineering 23:1, 57-70.
56. Sandrina Vilarinho, Isabel Lopes, José A. Oliveira. 2017. Preventive Maintenance Decisions through Maintenance Optimization Models: A Case Study. Procedia Manufacturing 11, 1170-1177.
57. Deepam Goyal, B.S. Pabla. 2015. Condition based maintenance of machine tools—A review. CIRP Journal of Manufacturing Science and Technology 10, 24-35.

58. Ali Azadeh, Seyed Mohammad Asadzadeh, Javad Seif. 2014. An integrated simulation-analysis of variance methodology for effective analysis of CBM alternatives. International Journal of Computer Integrated Manufacturing 27:7, 624-637.
59. Abdullah A. Alabdulkarim, Peter D. Ball, Ashutosh Tiwari. 2014. Influence of resources on maintenance operations with different asset monitoring levels. Business Process Management Journal 20:2, 195-212.
60. Cheong Peng Au-Yong, Azlan Shah Ali, Faizah Ahmad. 2014. Significant Characteristics of Scheduled and Condition-Based Maintenance in Office Buildings. Journal of Performance of Constructed Facilities 28:2, 257-263.
61. Marco Cococcioni, Beatrice Lazzerini, Sara Lioba Volpi. 2013. Robust Diagnosis of Rolling Element Bearings Based on Classification Techniques. IEEE Transactions on Industrial Informatics 9:4, 2256-2263.
62. Beatrice Lazzerini, Sara Lioba Volpi. 2013. Classifier ensembles to improve the robustness to noise of bearing fault diagnosis. Pattern Analysis and Applications 16:2, 235-251.
63. Lydie P. M. Smets, Geert-Jan van Houtum, Fred Langerak. 2012. Design for availability: A holistic approach to create value for manufacturers and customers of capital goods. Journal of Systems Science and Systems Engineering 21:4, 403-421.
64. Wenbin Wang. 2012. An overview of the recent advances in delay-time-based maintenance modelling. Reliability Engineering & System Safety 106, 165-178.
65. Van Tung Tran, Bo-Suk Yang. 2012. An intelligent condition-based maintenance platform for rotating machinery. Expert Systems with Applications 39:3, 2977-2988.
66. Amit Shinde, George Church, Mani Janakiram, George Runger. 2011. Feature extraction and classification models for high-dimensional profile data. Quality and Reliability Engineering International 27:7, 885-893.
67. Luis Ribeiro, Jose Barata, Joao Ferreira. 2010. A co-Evolving Diagnostic Algorithm for Evolvable Production Systems: A Case of Learning. IFAC Proceedings Volumes 43:4, 126-131.