ARE YOU BUILDING IN OBSOLESCENCE TO MISSION CRITICAL INFRASTRUCTURE?

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Ross Kennedy
QHi Group Ltd- Exertherm
9-10 Allied Business Centre
Coldharbour Lane
Harpenden, Herts AL5 4UT
United Kingdom

Abstract - A seismic global shift is occurring which will affect every industry and particularly large-scale organizations with 24x7 operations and / or high downtime costs; it's called the Industrial Internet of Things (IIOT). Where critical mechanical machinery and electrical infrastructure will all be connected via the internet. This will enable the collection of "Big Data", e.g. vast amounts of data being collected from a multitude of equipment globally. This data will then be analyzed via Artificial Intelligence (AI), to recognize early symptoms of malfunction and thus predict what remedial action is required to avoid the failure and resultant downtime. It will also enable huge cost savings from the more efficient use / increased uptime that can be derived from continuous monitoring.

Sound far-fetched? It's already happening. Billions of dollars are being invested by the giants of the internet world in both A.I. and in cloud platforms. Cisco is predicting that cloud traffic will quadruple in just 3 years from now. Global OEM's are also recognizing the new subscription revenue opportunities this will create, and are also racing to position themselves to be ready for this next chapter in the "Data Revolution", where Data centers are the factories of the 21st century.

The essential first step is to embed sensors in the equipment which will "create" the data. No sensors = no data. An example of this is continuous thermal monitoring technology to detect and predict compromised joints / terminations in critical electrical infrastructure.

From an OEM perspective, the ability to access data from a global installed base opens up new revenue opportunities. This paper will examine the similarities between the switchgear market and the automotive market and look at possible new revenue services which will become available.

From an end user perspective, the key question today when specifying new build electrical switchgear, which will have a nominal life of 25-35 years, is how to best avoid building in obsolescence to such equipment, given the accelerating rate of technology changes. The answer clearly is embedded sensors, since without sensors data cannot be collected.

This paper will discuss the experience of a local major Middle East oil and gas organization, who recognized that the increase in Capex, will be hugely offset by the dividend of reduced lifetime maintenance costs and increased uptime. Fabrice Jadot, CTO- Industry, Schneider Electric is quoted that "It can be shown that by managing asset performance, a 30 to 50 percent reduction in total machine downtime is achievable".

Index Terms – Artificial Intelligence (AI), Thermal Monitoring, Asset Integrity, Internet of Things (IOT), Industrial Internet of Things (IIOT), reliability, condition monitoring, Big Data, cloud computing, remote monitoring.

I. INTRODUCTION

A. Definitions.

The first task in understanding the global shift which is occurring, and the ramifications which will result, is to define the various components which are combining to make such a huge impact.

(1)"Big Data":

This can be defined as data which in volume and /or complexity is so vast that current / traditional computing software and capacity cannot process it. This creates some specific challenges in capturing, storing, and analyzing such huge volumes of data.

Data is only useful when it can be utilized in a way which results in a beneficial outcome. If there is an inability to capture, store or analyze then "Big Data" is in itself pretty useless

(2)"The Cloud":

Put simply the cloud is in effect a type of computing which relies on the sharing of computer resources via the internet, where the term "The Cloud" is a metaphor for the internet. Thus it is a type of internet based computing where different services are delivered to an organization or personal computers or internet connected devices via the internet.

As a result complex problems and high volume data can be processed by using capacity on many computers in a network, which could not be achieved on any stand-alone computer.

(3)"Artificial Intelligence (AI)":

This can be described as the capability of a machine to imitate intelligent human behavior. That, of course, then requires a definition of what such behavior is comprised of.

The ability to learn can take several forms; at it simplest by trial and error, where several solutions may be attempted before one that works is found. This can be retained in memory, and when the same conditions exist the solution can be recalled. This method is known as rote learning.

The ability to apply past experience to similar new situations is much more challenging. An example would be the learning of a rule and then applying that rule to a new situation not previously encountered. This ability to generalize is referred to as “generalization”

Reasoning is a further metric by which intelligence can be measured. This ability can be classified as “deductive” or “inductive. The former reasoning is based on the truth of a premise guaranteeing the truth of the conclusion e.g. an article must be in either room A or room B. It is not in room A, therefore it must be in room B. Inductive reasoning is based on the truth of the premise supports a conclusion, but without guaranteeing it. This requires a level of reasoning relevant to the solution of a particular situation e.g. Joe prefers donuts to cupcakes, therefore he will eat the donut. This may be true but if the cupcake is a flavor he like he may eat the cupcake.

Problem solving is a search through a number of possibilities in order to arrive at an objective e.g. finding the winning moves required to win a board game.

Perception via the use of optical sensors combined with memory is an area where AI is quite advanced. An early example was “FREDDY” a robot with moving television eye and a pincer hand could recognize various objects and assemble simple items such as a toy car from a random heap of components. For a more modern application think of driverless cars.

Thus it can be seen that AI requires a combination of learning, reasoning, problem solving, and perception. This remains cutting edge technology, but remains a vital component if Big Data is to be utilized beneficially.

(4)”Industrial Internet of Things”

The final key component is not so much a component, more a concept of how the other components can be combined and beneficially utilized.

The concept can be described as a universe in which products with built in intelligence communicate and “connect” with other intelligent products via the internet to create or access data, upon which actions can be taken. IOT is mainly linked to describing the “connectivity of smart products for consumer use, e.g. cars, refrigerators, lighting systems, HVAC etc.

The Industrial Internet of Things (IIOT), is the internet connected universe of machines and industrial equipment, utilizing embedded sensors to capture data for analysis and/or subsequent action. It is this latter IIOT which we shall discuss further in this Paper, and specifically the advent of IIOT in electrical infrastructure, and how it is, and will further change the landscape of the manufacture, purchasing, operation, and maintenance of it.

B. Previous revolutions which changed society.

There have been a number of global revolutions, each had the effect of dramatically changing the way we live, and the very fabric of society. The Agricultural revolution during the period 1700 > 1800 involved the introduction of the enclosure of fields, crop rotation, use of fertilizers, and the introduction of mechanical aids such as the seed drill , water mills irrigation etc. This significantly improved the efficiency of crop growing and reduced the levels of manpower required for agricultural produce.

The social effects were significant in creating unemployment in rural areas, which resulted in the emergence of cottage industries i.e. households manufacturing finished goods by hand or with minimal hand held tools, such as textile garments, leather goods, shoes, etc.

There remained a high dependence on the land to provide either the crops or animals to be converted into food, or to provide the raw materials from which households could manufacture finished goods e.g. woolen or leather garments.

By 1800 there had begun a new revolution, now known as the first “Industrial Revolution”. This involved the invention and manufacture of water and steam powered machinery to mechanize the manufacture of finished goods. This revolution more than any previous “technical” revolution also created fundamental changes to the fabric of society. The creation of factories meant there was an increased demand for labor to be in close proximity to the factory, which created a population shift from rural to urban locations in towns and cities.

Whereas in previous generations how a person lived was very similar to the way their parents lived, this now began to change as a result of the introduction of steam and water powered machinery. There was an increased demand for people who could both operate machinery and also maintain, and repair it. The need for education of the population began to increase. For the first time the offspring could have greater knowledge than their elders.

Various inventions including the Spinning Jenny (1764), steam engine with gears (1774), power loom 1785, internal combustion engine (1876), fundamentally changed both what could be converted into mass produced finished goods e.g. iron, steel, as well as textiles, household goods etc. This effectively took away much of the livelihood on which the cottage industries relied, accelerating the population move from rural to urban centers.

Britain was at the center of this “revolution” because it was in a unique position due to its historical naval superiority, which had allowed to colonize overseas countries which it discovered conquered, creating the “British Empire”. The phrase “the sun never sets on the British Empire” was based on the global reach of its empire both East & West.

As a result Britain was in a unique position of having unparalleled access to raw materials such as cotton, & iron ore, which fueled the manufacture of finished goods which could be sold to the rest of the world. By the end of the 1st industrial revolution at the end of the 19th century and the beginning of the 20th century, it had made Britain a manufacturing superpower, with the biggest economy in the world. However, that position was to be short lived, following two world wars which drained Britain economically, and was further eroded as it’s colonies demanded independence e.g. America 1776.

Note how the duration between technical revolutions had already begun to shorten. Until now the duration between discoveries, inventions, and their widespread use had taken hundreds of years (sometimes thousands). This was partly due to communication being largely physical e.g. the only way to communicate was to be face to face or to have someone deliver a message by hand.

By the end of the 19th century the Telegraph had been invented (1844) allowing messages to be transmitted along wires over long distance, however, it was slow in being universally adopted and took until the early 20th century to reach a peak deployment. It would be quickly overtaken by the invention of the telephone (1876), which enabled speech to be transmitted over cables. These two inventions were a cataclysmic change in the way knowledge could be transmitted and transferred quickly.

By the beginning of the 20th century we began to enter the 2nd industrial revolution. Inventions such as electricity, light bulbs, were perhaps among the most fundamental in changing the course of industry and indeed society. The speed with which these new inventions were deployed also shortened. Now the timespan between the 1st and second industrial revolution had shortened to a single century.

The use of electricity led to the growth of the assembly line (Henry Ford), and mass production techniques, using conveyor systems, and the division of labor. The ability to have artificial light enabled efficient product to continue for longer periods during darkness, further increasing productivity and economic growth.

The 3rd industrial revolution resulted from the invention and introduction of the automation of production processes. The first PLC was the Modicon in 1969. From the 1980's computers had begun to emerge, although slow, expensive and limited memory in comparison to current product.

The calculations required by NASA for John Glen to orbit the earth in 1962 were done by hand (see the film "Hidden Figures!).

The growth of automation increased exponentially through the 1950's and 60's, but would pale in comparison to the subsequent growth in the computerization of industry, via software designed to do tasks in seconds which would take humans hours if not days.

Note now how the duration is again shortening to decades between global seismic shifts in industry and society. The pace of change was accelerating and with it the resultant changes in society.

By 2000, we began to enter the initial phase of the 4th industrial revolution. Like all pervious revolutions it was not a single invention or discovery, but rather series of interdependent or linked ones, each leading to further ones.

Probably the most globally changing technologies in this first phase has been telecommunications and the growth of the wireless mobile phone, (although perhaps mobile computer would be more accurate).

This linked with the internet (1983) which was the linking together of networks using TCP/IP, saw the increased power of multiple computers rather than the limitation of one. In 1990 Tim Berners-Lee developed the World Wide Web, which is in essence a language using protocols to communicate over the internet. The most frequent and recognizable are:

HTML (Hypertext mark-up language**)** - The language that we write our web pages in;

HTTP (Hypertext Transfer Protocol**)** - this is the most common protocol. It was developed specifically for the World Wide Web and favoured for its simplicity and speed. This protocol requests the 'HTML' document from the server and serves it to the browser;

URL (Uniform resource locator) - the last part of the puzzle required to allow the web to work is a URL. This is the address which indicates where any given document lives on the web.

These two linked developments have been responsible for spawning vast new industries in telecommunications equipment and the infrastructure required to operate it, together with fundamentally changing both business and social communications e.g. social media, email, skype etc.

Once again it can be seen that the pace of change is continuing to accelerate, now down to one or two decades, in some instances even within a decade.

We now stand on the threshold of the next phase – the Digital phase of the 4th industrial revolution. This has been described as:

"The possibilities of billions of people connected by mobile devices, with unprecedented processing power, storage capacity, and access to knowledge, are unlimited. And these possibilities will be multiplied by emerging technology breakthroughs in fields such as artificial intelligence, robotics, the Internet of Thing, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing." (1)

However, for the purposes of the Paper we should distinguish between the Internet of Things (IOT), which is people being connected to each other and to domestic goods (including vehicles, refrigerators, lighting, heating and security systems etc.), and the Industrial Internet of Things (IIOT), which is industrial machinery and equipment being connected to each other and to businesses who will receive, analyze, and utilize big data and even operate equipment remotely in the most cost efficient manner, maximizing uptime.

C. The Digital Revolution Phase.

As we have described above, like all previous technical revolutions, the 4th Industrial Revolution is not a single invention or discovery, but a series of often linked events, often one following on from another. An example is the internet led to the World Wide Web, which in turn spawned online commerce.

We have already entered the digital phase, largely in the field of consumer / domestic applications. You can already control, lighting, heating, cooking, security systems etc. from your mobile phone. We are fast approaching a point where all new houses will come pre-equipped with hardware which can be connected to and operated remotely by the householder.

On-line commerce is now accounting for US$1.86 TN and is projected to increase to US$4.48 TN by 2021; that's growth of 240% over a 5 year period.(2)

This has created monoliths such as Amazon who now account for 16% of global retail e-commerce, and Alibaba who own Taobao & TMall which jointly account for 27% share.(3) This reflects the exponential growth of e-commerce in China, and India, Indonesia, Malaysia, where their share of global e-commerce is increasing, while USA's share is decreasing ,22% in 2015 reducing to 16% by 2021.(4)

Perhaps a pointer to how IIOT will benefit manufacturers, (and if there is no financial benefit then history shows that without this key driver inventions and developments will not progress), is to examine the automobile industry and how it was an early adopter of the principle of IIOT, even before the ability to remotely connect existed.

There are some interesting parallels between the automobile industry and the electrical switchgear industry. Both make product which is suffering from over capacity, resulting in relatively low margins on the hardware product. As a result the OEM's look to add value with lucrative additional features. One of the areas where continuing revenue and margin could be obtained is via the servicing and maintenance of the product. However, while this was easy to retain during the product warranty period, once beyond that period the majority of this lucrative area was lost to third party contractors who could undercut the pricing levels of the OEM's because they operated without the huge overheads.

The automobile industry set about a program to combat this situation and recover and retain the lucrative servicing and maintenance work. They did so by introducing diagnostic computer chips into the product, but these were coded so that the data they produced could only be accessed by authorized people. This simple step enabled the vehicle manufacturers to recover and retain a significant increase in servicing and maintenance beyond the warranty period. In particular this applied to the premium end of the market, but also led to OEM's offering increased periods of warranty, and incentives such as free roadside assistance provided, only they service or carry out repairs to the vehicle.

What can be seen more recently with the advances in internet connectivity is that the vehicle can be connected to, and even controlled by the OEM. Diagnostic chips provide an on-going stream of data, which can predict faults at an early stage of development, advise when fluid levels need replenishing, and when servicing is required.

The advent of Big Data + A.I. now enable the OEM's to obtain vast amounts of data from every vehicle they manufacture and from the resulting analysis, will be able to refine and improve their product, identify which components have the best performance, and increase their profitability by reducing warranty claims resulting from faults, together with driving the procurement process to maximize efficiency and cost savings.

A similar set of circumstances exist in the electrical switchgear market. There is global over capacity, margins on hardware are low, and maintenance is often lost beyond the warranty period, which like the previous set of circumstances in the automobile industry is set at a "norm" of one year.

The advent of IIOT is about to change things. It will affect every industry, it will be global, and it will be seismic in the way it will change the procurement, operations, and maintenance of electrical infrastructure. The pace of change will also continue to accelerate. Consider that since 2000, 52% of Fortune 500 Companies have disappeared, (some being attributable to mergers and acquisitions). The life expectancy of a Fortune 500 Company in 1955 was 75 years. In 2015 it is 15 years. (5)

II. OWNERSHIP AND ACCESS TO DATA IS KEY

A. *OEM or End User.*

The creation of vast amounts of data obviously requires sensors being placed within very large quantities of equipment. The OEM's will be ideally positioned to install the sensors during the manufacturing process. However, because the market for electrical infrastructure is highly competitive and price sensitive, we remain in a phase where despite the major OEM's recognizing the potential advantages of installing sensors, they remain nervous of increasing prices as a result of including condition monitoring sensors, and risking losing orders to competitors who offer lower prices without including sensors.

The result is that currently OEM's are including condition monitoring sensors where it is specified by the customer. Consequently they are risking losing ownership of the data being created. However, there is an increasing recognition by the 5 main global OEM's,that they must start to prepare for the inevitable growth of IIOT. As a result they have begun the process of designing condition monitoring sensors into their product, but remain hesitant in offering it other than as an optional extra. This is the current situation which exists for large scale customers of the major OEM's who capture the majority of large scale projects globally.

The situation for the huge number of smaller scale regional / national OEM's and their customers, who make up the bulk of the total global market, remains one where the OEM's operate in a market where price dominates the purchasing decisions of their customers, who are also generally of a much smaller scale than those of the global OEM's. Consequently, the vast majority of these smaller scale OEM's remain some considerable way behind the global majors in adopting policies to adapt their products to include condition monitoring sensors.

As indicated above, the global OEM's are in a position currently, where they risk losing ownership of data, because they are installing sensors only when it is specified by their customer. It is the customer who then obtains the data that is created from the sensors and it is the end user customer who will then utilize the data to obtain the potential benefits which arise from that analysis.

This situation will change as the exponential growth of A.I. advances the realistic opportunity to reap the available benefits that come from ownership of the data. However, this change will not come about without some considerable levels of conflict between OEM and end user customer regarding who owns the data, or even who has access to the data.

B. The Cyber security threat.

An example of this could be the data center industry, where any remote access to IT networks is often prohibited, as a security risk. As cyber-crime and state sponsored espionage / sabotage is increasing, so too do the risks associated with allowing remote access to IT networks. We are already observing that major end users in the oil and gas industry are also now becoming aware of the potential risks to mission critical infrastructure that could occur if remote access to IT networks is allowed, and thus prohibiting such remote access from their operations around the world.

Clearly cyber security risks will be a major issue. If these risks cannot be minimized to an acceptable level it will mean that the cloud based platforms on which Big Data will reside will be considered too great a risk to the operational security of major industries. It remains to be seen if this security issue can be resolved. However, the assumption appears to be that sufficient levels of secure data transmission will be achieved, thus allowing the potential benefits of IIOT to be obtained.

III. THE OPPORTUNITY

A. Market Size.

It is important this is broken down into the new build per year and the existing level of infrastructure available for retro-fit. Also in realistic terms it will be the segment of the market which services high downtime cost industries such as oil & gas, data centers, utilities, automotive, and other large scale industries.

The new build market for LV & MV switchgear is estimated to be worth $2.3bn p.a. by 2019 [(6)]. This equipment has a nominal life of 25 years so a conservative estimate would be a factor of 15 to provide an installed base worth $34.5bn. However, if we assume only 25% of the market would be an applicable market for high downtime mission critical applications it still provides a market for new build worth circa $600m p.a. and retro-fit of $8.6bn

Similarly, the market size for MCC product equates to circa 15m “devices” (e.g. drawers / buckets), of new build equipment p.a.[(7)]

Using the same criteria as for switchgear this would provide an installed base of circa 225m devices. Again, on the assumption only 25% is in applications which are high downtime then this still provides 3.75m devices p.a. and 56m devices available for retro-fit.

The above figures are deliberately conservative, but still indicate a huge market potential not just for sensor hardware, but also for the associated services of turning data into commercial information which can be used to obtain the benefits available from IIOT.

B. Contractor v OEM Services.

As indicated above the growth of IIOT provides OEM’s with a new opportunity to increase profit margins by adding value via the inclusion of condition monitoring sensors embedded in the electrical infrastructure products. As can be seen from the above figures relating to market size, while the new build market is big, the retro-fit market is, by comparison, vast. This presents a further huge opportunity to retro-fit condition monitoring sensors into existing equipment.

Global economic conditions have resulted in a requirement in many end user organizations in the oil & gas segment, (which suffered the collapse of oil prices), to make existing infrastructure last longer, rather than replace it with new equipment. A direct consequence of this is an increase in the frequency of failures, and linked to this is an increase in the safety risk.

While not a magic panacea, condition monitoring sensors which can detect the tell- tale symptoms of a potential failure at an early stage of development, and thus provide a warning in advance of the failure, can assist in reducing outages, thereby combining increased operational uptime, and the associated levels of safety.

Arc flash and faults related to bad joint connections are one of the most common causes of power outages and are likely to increase as electrical infrastructure ages. They thus provide an example of how thermal monitoring sensors can be installed to detect, and identify the location of potential faults of this type in advance, allowing remedial work to be undertaken via planned maintenance “as required”, as opposed to periodic inspections / maintenance.

OEM service departments compete in the contractor segment of the market. We have discussed above how the OEM’s can retain on-going maintenance of their products via the introduction of “smart” product, where access to the data is limited to them. This retro-fit market provides a further huge opportunity for them to fit condition monitoring sensors (e.g. thermal sensors), which will give them the opportunity to provide 24x7 cover remotely, via monitoring centers staffed by engineers (or in the future by A.I. computers), who can interpret the data rather than the need to be physically present on a permanent or periodic basis. This gives the OEM the benefit of cost reduction combined with increased levels of service coverage to the customer which combine to provide higher profit margins for the OEM. There are predictions that the services element will be the major contributor of profits to OEM’s rather than the hardware product element, where margins are under continual pressure.

While the opportunity for the major OEM’s is significant, the opportunity for contractors is considerably larger, since the number of smaller organizations who require contractor services is the major portion of the global market. As the OEM’s fight to retain the on-going maintenance revenues on their product via the control of access to the data created from their sensors, so the contractors will focus on retro-fitting condition monitoring sensors to existing infrastructure and offering remote 24x7 monitoring to their customers in a similar way to that of the OEM’s. Obtaining access to the data will be a key battleground.

IV. RELIABILITY – A FUNDAMENTAL ISSUE

A. Sensor technology and reliability.

The installation of permanently installed sensors is essential for the ability to create the required data – no sensors = no data. The electrical infrastructure into which sensor will be installed has a nominal operational life expectancy of 25 years, which in reality can be extended to circa 40 years.

Thus in selecting the sensors to be installed it is of paramount importance to select sensors which can provide the desired level of proven accuracy and reliability e.g. they will last the lifetime of the infrastructure into which they are installed.

Having made the decision to invest in installing condition monitoring sensors, the worst subsequent decision will be to install sensors which will require subsequent maintenance themselves or even replacement of the sensor or any component part, since they will generally be installed within enclosed panels which require de-energizing (and thus the associated downtime costs), in order to gain access to the sensors.

As the IIOT market grows, so too will the introduction of sensors which employ "smoke and mirrors" marketing techniques to exaggerate the quality and reliability of the sensors. It will thus be important for both OEM's, end user organizations, and contractors to be diligent in ensuring they only install sensors which will not result in requiring maintenance or replacement for the entire life of the equipment into which they are installed, indeed they should only select sensors which offer a lifetime warranty and zero maintenance guarantee.

This issue of sensor reliability is also important in terms of the potential reputational damage if sensors are installed by an OEM or contractor, which subsequently require downtime to perform maintenance / replacement, as this will incur operational downtime costs by the customer, who quite rightly, will question why he has to incur such costs.

B. Reliability via market structure change.

Currently the electrical infrastructure market structure operates in a similar way to many capital goods industry segments. An end user customer has a requirement for new equipment, a specification is produced, this will often go out to tender, offers are received, a manufacturer is selected, and a PO issued. The goods are then paid for on satisfactory project completion. The OEM will provide maintenance during the warranty period, which will then often be lost to third party contractors for the remainder of the product operational life.

With the introduction of IIOT the OEM is now best placed to install condition monitoring sensors at the point of manufacture, and to gain exclusive access to the data which is created. This then provides the opportunity to retain maintenance for the life of the product by providing 24x 7 remote condition monitoring services to the client. It becomes much more difficult for a contractor to take this business away from the OEM, (remember the analogy of the automotive market).

However, there is the potential for the OEM's to further entrench their dominant position by changing the structure of the market from one where they sell the infrastructure to one where they lease it.

The core business of the OEM customers is not electrical infrastructure. In the oil and gas industry it is about the extraction, refining, processing, and transportation of oil and gas. The electrical infrastructure is merely the provider of the electrical power that is required for the operational requirements.

If the OEM took the stance that if the customer can provide them with a sufficient understanding of the power requirements, then the OEM will undertake to design, construct, supply and maintain the equipment on a lease basis. The lease would be for a defined period, and the OEM would undertake to provide a reliability guarantee, on the basis only the OEM can maintain the equipment.

The design of equipment would become more efficient as A.I. would enable identification of component weaknesses which were the cause of problems. Designs could be more standardized, resulting in more efficient production, cost savings

This would be possible if the benefits which can be derived from IIOT where obtained by the OEM. It would provide them long term guaranteed increased revenues, since leasing of capital goods is a well-established sector of the financial services industry.

From the perspective of the end user organizations, this would provide them a level of increased reliability, which in turn would create maximization of uptime and increased levels of safety.

In discussion with two of the global OEM's they have confirmed that they are already advanced in discussing internally the possibility of offering product on a lease basis. We will have to await what this type of offer comprises and how quickly it emerges in the market.

V. WHAT'S IN IT FOR ME?

A. Advantages IIOT can bring for the OEM.

IIOT is all about scale, the larger the organization the more potential benefits can be derived. For the global OEM who have a vast estate of product installed globally there are operational / production benefits which they can obtain which include:

- Standardization of design
- Identification of components with best cost benefit performance
- Improved efficiency on production line
- Improved efficiency of component procurement
- Increased levels of product performance and reliability
- Reduced warranty claims

In addition as identified above, IIOT also provides the opportunity to retain ownership of data in installed equipment, and thus offer new avenues of profitable revenue streams via retention of maintenance.

It also provides further new revenue streams from retro-fitting condition monitoring sensors into the huge market of existing equipment, while reducing operational costs of providing maintenance which can be obtained by reducing the need for the physical on-site presence to conduct inspections and or periodic maintenance, which would now be carried out on the more efficient "as required" basis.

B. Advantages IIOT can bring to the Contractor.

The current business model for contracting businesses is to supply physical periodic inspection and maintenance either on a time basis e.g. inspect or maintain annually, or every six months etc., irrespective of equipment condition, or maintain/ repair in event of equipment malfunction / failure. Competition in this sector is fierce, with the resultant pressure on profit margins. Often maintenance contracts are for relatively short durations, typically 3years, with new tenders being issued, inviting quotes from which a contractor will be selected; often on the promise of reduced cost. This pressure on lower costs often results in lower performance resulting from corner cutting at every available opportunity, be it quality of staff, to cursory inspections etc. , than was anticipated. Ultimately this lack of quality at the inspection / maintenance level results in a reduced level of efficiency in maximizing uptime resulting from increased levels of equipment failures of the end user customer.

IIOT will be a highly disruptive force in this segment of the market. Contractors who have the resources and who move quickly to adopt policies which enable them to adapt to the new opportunities will be best placed to reap the rewards available. However, this will involve them in a significant change in how they provide services to customers.

If they are prepared to share with the customer the investment in retro-fitting condition monitoring sensors to equipment, or absorb all the cost (excluding the customer downtime costs), this will provide a new opportunity to have exclusive access to the data. This can then be used to provide 24x 7 remote monitoring of equipment, which in turn results in significant cost savings from reduced levels of physical on-site presence to perform time based inspections and maintenance, being replaced by a single remote monitoring center where various customer equipment on various sites can be monitored 24 x 7.

This provides an improved level of continuous monitoring to the customer, while significantly reducing operational costs of the contractor. An additional benefit is that this level of monitoring combined with A.I. will result in an ability to predict faults in advance, leading to improved efficiency, so it is a win /win situation.

Once again, ownership of data will become a key factor. For contractors who pay for or share the cost of installing IIOT equipment into the customers infrastructure and machinery it will mean it cements their relationship with the customer, resulting in longer contractual partnerships, since it will become much harder for competitors to dislodge them purely on a price basis, unless they are also willing to buy out the investment in IIOT equipment.

C. Advantages IIOT can bring to the End User

The end users in the oil and gas industry, because of the scale of investment required in both the upstream and downstream elements, spread over a global estate of sites both onshore and offshore, are well placed to benefit from the advantages available from IIOT.

The collapse of the oil prices led to an urgent need to maximize and improve the level of efficiency in upstream and downstream processes. This coupled with significant cost cutting has led to a more efficient industry, who are now able to be profitable at much lower levels of global oil pricing.

This also drove the recognition that the adoption of IIOT was the way forward. This was illustrated in a major Greenfield project, where the oil Company was asked why they were designing so many condition monitoring sensors into their electrical infrastructure. The answer was they did not want to incur any downtime which would be required by the need for physical inspections. When asked how they would utilize the data being created, the answer was even more revealing.

It was that IIOT would be in two parts, the first would be the investment in the installation of sensors which would create uniform data, which could be transmitted to remote monitoring centers. The second part would be the investment on the software analytics to transform the data into commercially useful information. What they saw was that investment in the first part was necessary, albeit they did not yet know or fully understand how it would be integrated and utilized with other data to maximize efficiencies in their operation. However, what they recognized was that it was not important to know that at this stage, since the pace of development in A.I. meant that it would increase and change at an accelerating level. It was though vital that they install the sensors into all the new build electrical infrastructure now, since it was the most cost efficient time to do so, and without sensors there would be no data and the available benefits of IIOT would become unavailable, unless they subsequently installed sensors, which would incur huge costs resulting from additional production downtime etc. Hence the decision to install the sensors at the manufacturing point, which is the lowest cost point.

The benefits which will be available to end user organizations will be:

- Standardization of upstream and downstream facilities design , leading to lower design costs
- Identification of equipment with best performance profiles leading to reduced levels of equipment failure
- Uniformity of data from sensors rather than via humans, enabling best use of A.I. analytics
- Increased safety resulting from reduced failures and physical inspections / maintenance.
- Reduced Opex spend in on-site staffing levels
- Increased efficiencies in the procurement process
- Increased bottom line performance driven by increased efficiency across all operational sectors of the business

The importance of this has already been recognized by a major end user organization in the UAE. They have installed over 1,500 infrared thermal sensors in their 11Kv and 3.3Kv MV switchgear. It has already paid dividends by detecting faults which would have resulted in outages, and they are now including this in their new build specifications for both MV & LV switchgear. This forward thinking approach has also enabled the foundations to be in place for further expansion and integration of data and it's analysis as part of the policy of preparing for IIOT and maximizing its advantages.

VI. CONCLUSION

IIOT is not a sophisticated sales pitch to sell product, it is a global seismic change which has already commenced; is growing at a significant rate; and will affect every major industry globally. It is estimated by Gartner that there were 6.4 billion IIOT "things" connected to the internet in 2016, and this is set to increase to 20.8 billion by 2020[8] – that is now just two years away.

Predictive maintenance is estimated to save up to 12% compared to time based scheduled maintenance, reducing overall maintenance costs by up to 30% and eliminating equipment failures by up to 70%.

Cisco predict that the growth in cloud based data will grow from 3.5 zettabytes in 2016 to 14 zettabytes by 2020, a zettabyte is one trillion gigabytes). That is an eye watering level of predicted growth, and comes from an organization well placed to see over the horizon.

The message then is simple. Doing nothing is not an option. To ignore the fact that IIOT is going to happen and that it will affect your business will result in serious consequences in the future – remember Kodak!

IIOT is going to affect all aspects of the oil & gas industry, upstream, downstream, onshore, offshore, marine, pipeline etc. It will affect OEM suppliers of infrastructure and machinery, and the contracting sector. It will be highly disruptive, but the lesson of history is that it will bring greater efficiency and with it new opportunities, and that it will be a change for the better.

The lesson of history all shows that those who ignore this latest revolution risk future survival, no matter how big or dominant they currently are; but also that those who adapt and adopt quickly will be best placed to increase their market size and position and solidify the ability to increase their profitability.

At the heart of IIOT is the creation of data. Without sensors there is no data, with the result that the benefits of IIOT are unavailable. Consequently, there is a growing recognition that for OEM's it will become essential, if they are to remain competitive, that they offer designed in condition monitoring sensors as part of their standard product offer.

They should also now begin to consider changes to the business model such as leasing, to improve profits which IIOT will make more possible.

For end user organizations, it is vital they understand that they must now include condition monitoring sensors in their specifications of new electrical infrastructure, because if they do not then they are building in obsolescence into every new panel which has a nominal life of 25 > 40 years. The cost of subsequently installing them will be 3-5 times the cost of installing them at the point of manufacture. In short it will be a strategic investment mistake.

For contractors, it is equally important they recognize the changes which are likely to happen as a result of IIOT. Once again those who adapt and adopt at an early stage will be best placed to take advantage of IIOT, while those who ignore it will find it much harder to catch up, or even survive in the new order.

Applicable to all will be the issue of reliability of sensors. Having made the decision to invest in sensors to create data with the objective of reducing costs and increasing production uptime, the worst subsequent decision will be to install sensors which require maintenance and/ or replacement during the lifetime of the equipment, as this will incur on-going additional costs, often with the additional cost of expensive downtime. As the sensor market increases to cope with this new demand level, there will be many sensors which appear on the market which promise more than they actually deliver.

It is thus essential that sensor selection should incorporate a specification that the sensors offer lifetime warranty with zero maintenance, with a proven track record of successful deployment.

A further issue applicable to all will be cyber security. This will pose many challenges and inevitably it will be a never ending battle between those wishing to protect the data and those wishing to hack into it for criminal, or state sponsored terrorist, espionage, or political reasons. While these risks are real, and there will be breaches, if we look at the effect similar risks have had on on-line commerce globally it is fairly minimal in terms of the growth that continues to accelerate.

As history has shown with every previous stage of industrial revolution, change is inevitable, and those who embrace the change will be winners, those who resist or ignore the changes will become losers.

VIII NOMENCLATURE

IOT	Internet of Things
IIOT	Industrial Internet of Things
A.I.	Artificial Intelligence
UPS	Uninterruptible Power Supply
OEM	Original Equipment Manufacturer

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Ross Kennedy is Founder & CEO of the QHi-Group, providing innovative, technology-based solutions to a diverse cross section of industry for over 20 years. Prior to setting up QHi-Group, he had a successful career in international management positions with Reed International, Turner & Newall, & Unilever. Subsequently he founded and sold successful businesses in the Printing and also the Rail industry. Ross has pioneered the use of innovative technology for continuous thermal monitoring of electrical infrastructure, utilizing unique infrared technology, and its application in the IIOT revolution.