Power Generating Equipment in Palm Oil Mills: *e*-Maintenance Network Concept for Malaysia

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Abstract

Malaysian government's renewable energy efforts promote the biomass power generation and co-generation in the palm oil mills with the aim to reduce greenhouse gas emissions, promote growth of power generation and co-generation, and reduce barriers that have hindered the adoption of biomass power generation and cogeneration technologies. Though the private maintenance service providers active in the Malaysian power generating market are providing this service, to some extent, their traditional way of handling the maintenance business, based on the transactional and price oriented business models, is not aligned to the new market requirements. To bridge the gap of policy and practice of providing maintenance services to the biomass power generating sector, this paper proposes a generic, e-maintenance network concept for maintaining Power Generating Equipment in Palm Oil Mills. Utilizing intelligent condition monitoring strategies and a supervisory on-line diagnostic system, it will manage comprehensive on-line data acquisition; internet data transmission systems, task-related data analysis and an expert background knowledge base at, strategically located, Remote Power Generation Diagnostic Center (RPGDC).This will enable detailed diagnosis of the actual plant condition for the power plant and its key components. New approach will help reduce the transactional costs by establishing strategic alliances between the service suppliers on the one side and the palm oil mills on the other.

Key Words: *Biomass Power Generation, Power Generating Equipment, e-Maintenance, Palm Oil Mills*

INTRODUCTION

There are 434 palm oil mills operating in Malaysia; with 18 million tons of crude palm oil production capacity per year, the oil palm mills, at five times the rate of CPO production, generate 90 million tons of biomass available for power generation (MPOC, 2010). As demand for sustainable energy from clean indigenous sources becomes more pressing, the Government is actively promoting the utilisation of biomass feedstock such as empty fruit branches (EFB) and palm oil mill effluent, which are envisaged to take up an increasing stake in Malaysia's electric power generation. Oil palm plantation players, particularly millers, are strongly urged to actively harness the abundant oil palm biomass derived from the country's large oil palm plantation operations. To date, there are 411 local palm oil millers with the potential to be independent power producers (IPPs) of sustainable green energy (PalmOilHQ, 2010). Coordinated projects have been developed to curb the growth of greenhouse gas emissions from fossil fuel fired combustion processes and unutilized biomass waste (Wan *et al.*, 2010). They aim to make use of unutilized biomass waste through installation of power generating capacity by using cogeneration technology, also known as CHP - combined heat and power. This development has been targeted through four distinct objectives: Reduce greenhouse gas emissions; Promote growth of power generation and co-generation; Reduce barriers that have hindered the adoption of biomass power generation and cogeneration technologies. In the 21st century, energy producers must meet environmental targets, leading to a shift away from fossil fuels and towards renewable sources of energy; as a result biomass is becoming an increasingly attractive option to energy providers. Biomass is simple and cost effective; with some estimates predicting that by 2050, it could provide 50% of the worlds' primary energy needs. The next ten years will see the development of efficient systems to convert biomass into electricity and spur the development of a fast growth of new global bio-power industry (RESEARCHANDMARKETS, 2012).

Private maintenance service providers active in the Malaysian power generating market are, to some extent, successfully bridging the gap of policy and practice of providing maintenance services to the

biomass power generating sector; however, palm oil mills need to carefully explore the possibility of engaging the right supplier with proven track record of providing such service, preferably, Original Equipment Manufacturers (OEM) with extensive Operation & Maintenance (O&M) field experience. Prevailing market conditions in the oil palm milling sector require a higher flexibility in operating and maintaining the power plants that is vital to smooth operation of palm oil mills. Older base load units have to cycle, that creates higher stresses to the materials; planned overhauls are postponed to avoid uneconomic standstill time. Up rating of power output of existing units to the absolute design limits is often used as an additional option to catch maximum profit during high price periods. Beside these market demands the operation of the complete power plant with the steam turbine set and generator as key components need to be enhanced by higher reliability, availability and utilization.

The traditional way of handling the maintenance business is not aligned to these market requirements, because it is based on transactional and price oriented business models. The contractual parties are focusing unilateral objectives, which normally are different from each other, and trying to reach them separately. As a result, a lot of resources are deployed for the awarding process. Orders have to be prepared and evaluated for different work scopes and the packages have to be negotiated by the parties. All this leads to high transactional costs. One way to reduce the transactional costs is to establish strategic alliances between the service suppliers on the one side and the palm oil mills on the other. These tailor made contracts should be the basis to leave the transactional business behind and to enter value based and success depending business models or contracts; critical factors for the successful alignment of the objectives and the definition of benchmark matrices (Score Cards) to measure the level of success. The range of these strategic alliances can vary from simple parts availability programs or operating plant service agreements to long term programs with risk sharing elements and the value based payment. In addition these aims could be achieved more efficiently by using intelligent condition monitoring strategies for the power plant and its key components using a supervisory on-line diagnostic system. The use of comprehensive on-line data acquisition, internet data transmission systems, task-related data analysis and an expert background knowledge base at Remote Power Generation Diagnostic Center (RPGDC) can enable detailed diagnosis of the actual plant condition in real time. Ever since boost in information technology took place, allowing the transfer of large masses of data over long distances, Siemens of Germany has been a vanguard of research to use remote monitoring to mitigate risk for long term service contracts. Although Siemens' first remote monitoring center, outside Germany, was established in Florida, USA, in late 1999; the continuous remote online monitoring was officially introduced in February 2002 to enable both customers and OEM to mitigate risk on a 24/7 basis (Brummel, 2006).

With human expert support and engineering solutions from the OEMs and O&M suppliers, together with the knowledge based supervisory diagnostic system, a long term condition based plant operation with enhanced reliability and profitability can be possible. The RPGDC will enable the palm oil mill clients to: Make inspection decisions on turbo set components on a condition and risk based maintenance strategy; Better life time management under technical and commercial aspects; Smoother turbo set operation to avoid frequent overstressing the equipment which will result in life extension. Condition monitoring with appropriate power diagnostic tools leads to effective life cycle asset management.

REMOTE POWER GENERATION DIAGNOSTICS CENTER (RPGDC)

RPGDC is an essential part of the *e*-maintenance network that will enable operators to minimize the life cycle costs of power plants and at the same time maximize the output of electrical energy. The drive to reduce life cycle costs results among other things in the reduction of staff and labour costs, whereas the desire to maximize electrical output requires raising the availability, reliability and efficiency of the plant. The Power Plants covered under a long term service contract can be connected via satellite to the RPGDC established in strategic locations. The RPGDC has access to the data monitored continuously at the power

plant for all important operation values such as temperatures, vibrations, operation hours, turbine start-up curves, performance curves etc. Qualified and well experienced personnel monitor the data in RPGDC and analyze these values with the objective to: determine the actual conditions of systems and installed components; and evaluate the power plant performance. If needed, the RPGDC has direct access to specialised OEM engineering know-how, consultancy through specialists for, Generator or Steam turbine. In case of detected abnormal trends, events or trips, recommendations for predictive maintenance actions can be given; The RPGDC is one of the important features for early detection and prevention of damages. A concept diagram showing the Flow of data between RPGDC, power generating equipment, field service centers, and supplier's remote power diagnostic centers, is shown in Figure: 1.

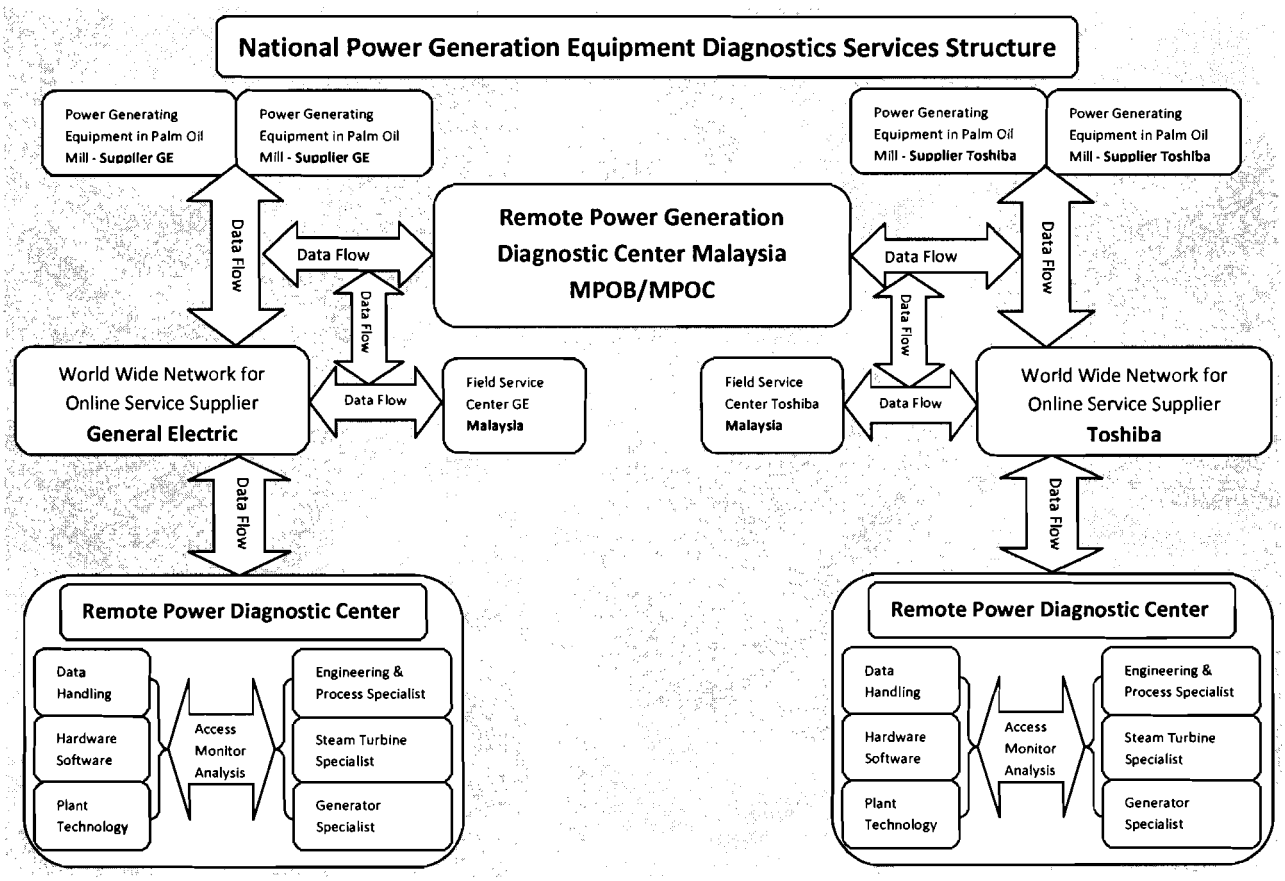

Figure: 1 RPGDC Concept for Palm Oil Mills

RPGDC will be a modular built system to monitor, analyze and diagnose the complete turbine island. The advanced service product will be equipped with sophisticated remote expert diagnostic system, a foundation, for condition based maintenance strategies and optimization of the plant operations. The recommendations of RPGDC will form the basis for further operations, repairs and/or modernization of customer's equipment. RPGDC services will be established on national level with links to the global service centre of service suppliers; its services will not be limited to a specific supplier but applicable to all kind of power generating equipment including steam turbines and generators. Malaysian Palm Oil Board (MPOB) and Malaysian Palm Oil Council (MPOC) can take a leading role, to get the palm oil mills involved, and be instrumental in establishing this institution. The goal of RPGDC would be to diagnose the operation of the turbine island for purpose of early detection of abnormal operating conditions. Hardware failures and instrumentation malfunctions may lead to abnormal conditions.

Detection of these conditions would result in optimized operation, higher availability, and improved turbine island efficiency. This service will benefit operations by mitigating running of nominal conditions. It will also provide the original manufacturers' key information that can be used to further improve products and services such as increases in hardware life and durability, mitigation of collateral equipment damage through early detection, improvement in reliability, and optimization of maintenance durations: Skilled OEM/O&M engineers and technicians, enabling them to make timely recommendations to customers, who can be used to help assess future actions, and analyze this information (Taud & Scheidel, 2004).

Managing Data

To reach the objective not only to monitor the different measured values but to implement a real diagnostics system, a global network of highly sophisticated experts is needed and the raw data of the turbo generator, process factors and state variables, have to be collected, correlated, and analyzed. There is no software solution for this in depth diagnostics available and may not be in the near future; this data evaluation has to be done by engineers. However, the software capable of learning the "normal behaviour" of a machine or a system, and to detect deviations from this normal behaviour, is available in the open market. It is, therefore, possible to set alarm and trip thresholds and to create intelligent and event driven data management systems. The software is to operate more or less like a watchdog or a filter, to make sure human experts are dealing with complex diagnostics issues only. The demarcation between monitoring, analysis and diagnostics is defined as follows:

I. Monitoring: Simple stand-alone-monitoring-systems will offer the possibility of visualization of all measured values and a simple comparison against defined thresholds; a detailed knowledge to define the alarm and/or trip level is needed even here. The System will consist of: Sensors; temperature, vibration, magnetic flux, and data from Instrument & Control (I&C); Data processing System; and Visualization Equipment that could be part of I&C System.

II. Analysis: The analysis system will be based on the data coming out of the monitoring system characterized by complex data calculation of interacting parameters. The software would be capable to create reference values which will form the basis for comparison of expected and actual values to the machine conditions. The System will consist of: Sensors; Processing of measured values; Personal PC; and Software for analysis.

III. Diagnostics: the diagnostic system will be set up on the results of the analysis and contain the measurement values and parameters, the identification of failures, disturbances and recommendations from a remote expert center. The software will be capable of learning the normal behaviour of a machine or a system during a period of time which would contain all different load factors and start up and shut down procedures. Data which cannot be explained by the process model, only, will be passed through to the human experts. The System will consist of: Sensors; Processing of measured values; Personal PC; Software for analysis; and RPGDC connectivity.

Due to the fast growing market of new sensor technology power diagnostics will be built up on a modular basis; in this way a high flexibility and a fast adoption to new developments can be achieved.

The critical factor of power diagnostics is the data processing including: On-site data acquisition and monitoring system, data infrastructure and collection, measurement and analysis of equipment conditions and performance, comparison of conditions to fleet equipment baselines - design specification and experiences, and communication of relevant data to RPGDC. Technical advice will comprise of: Identification and isolation of problems; Root-cause analysis and experience-based learning; and Data archiving and unit/machine analysis; Problem reporting and corrective action recommendation; and Identification and isolation of problems. The focus of RPGDC will be to bring together the core business

of the operator and the manufacturer to use their overlapping fields of experience to establish real condition based maintenance (CBM), derived on a relevant data input.

RPGDC will perform analysis and diagnostics using high sophisticated learning software modules that will be specifically selected for this purpose and provide trend analysis, problem identification and root-cause analysis done by human experts. The learning software solution will prevent them from dealing with trivial problems. The engineers in RPGDC will be comparing and analyzing the incoming data from the whole fleet connected to the diagnostics center. Because of the pool of information coming from a huge fleet, the experience will grow much faster than it would be possible for a single operator. Even when in the absence of problem the engineering experts will be able to generate recommendations on plant operations and/or maintenance actions; the recommendations designed to maximize the equipment's performance, reliability and availability and potentially extend outage interval cycles. The following diagnostic modules are readily available in the market today: Vibration Diagnostics - Shaft vibration, bearing vibration, end-winding vibration using fibre optic accelerometers; Thermodynamics Diagnostics - tool developed for plant design and engineering of the thermodynamic processes integrated in the online diagnostic to compare current process data with expected values.

Turbine Operability Improvement

Applying the historical steam turbine start-up philosophy either limits the operating flexibility or exceeds steam turbine allowable stresses increasing service consumption. The demand for flexible operation leads to the development of innovative concepts to reduce start-up times of steam turbines while minimizing service time consumption thereby improving availability. This new concepts include plant operability improvements, such as: steam turbine stress controller and stress monitoring system; high level of plant automation; plant systems designed to provide steam conditions necessary for a pre-selected start-up mode; and remote online monitoring and diagnostics. Online life consumption calculation contributes to improve turbine operability through Radio Frequency (RF) monitoring to detect faults in high-voltage equipment such as; generators, terminal lead area, transformers, and motors. To avoid repair costs or even loss of revenue due to unscheduled outages, it is necessary to identify these faults and rectify them in time (Killich, 2006).

Faults in electrical equipment do not occur suddenly but, in most cases, are announced in advance by telltale partial discharges. They short-circuit across part of the high voltage insulation and can be detected by radio frequency (RF) measurement methods because of their radio-frequency character. Suitable selection of RF measuring points allows detection of partial discharge sources over the entire high-voltage range. To avoid intervention in the insulation system of the components itself, natural coupling points are preferred. By digital unmasking of the partial discharge signals from the usually noisy complex mixture of RF signals it is possible to determine the causes of the discharge. With simultaneous measured data acquisition and different measuring points it is possible to locate the source of possible faults (Killich, 2006).

Data Acquisition Suitable for Diagnostics

The data acquisition requires the measuring of signals, which contain adequate information about the condition and condition changes of the respective machine. The data acquisition has to be carried out in a way that a considerable information loss doesn't occur in the measuring phase emphasising: Continuous signal recording; Recording of the operation regime as well as of the relevant measures of the process technology; and Data analysis and data reduction to informative code numbers suitable for diagnostic at minimal information loss. The objective is to reduce the data to informative characteristic quantities. The large amount of data has to concentrate on few representatives and qualitatively clear characteristic quantities, such as: Data preparation suitable for diagnostic for off-line diagnostic by experts; and Manual assessment of machine conditions. In the context of a diagnostic computer in on-line operation or of

stored data a variety of representations have to be selectable or over printer/plotter displayable, namely: Determination of the machine type and measuring place specific normal condition and normal behaviour of the characteristic quantities in the fluctuation area of normal operation parameters for the operation condition; Supervision suitable for diagnostic, i.e. automatic data assessment in the comparison with the values of the normal condition and normal behaviour with data storage at deviation of the normal condition as well as qualified machine protection. The tasks of supervision suitable for diagnostics consist in the comparison of the prevalent characteristic quantities with the characteristic quantities of the normal condition or the normal behaviour among the respective operation regime of the plant with following two functional aim positions in the variation area of the normal operation parameters; Plant protection - Condition changes of characteristic quantities which signal the plant endangering of the operational safety must be recognized in the interest of the quickest possible triggering of the machine protection; Control of the data storage - Condition changes of single characteristic quantities, which do not lie in the area of its normal behaviour, must be subjected to event-driven data storage.
The global network configuration shown earlier gives an idea of the performance of the plant diagnostics integrated into the supplier's intranet. The RPGDC is located in the middle. Worldwide secure modem connections establish the data links to the individual plants and their 'Server installations'. For qualified assessment of diagnostic findings, links to the various centers of knowledge (competence) i.e. steam turbines, gas turbines, generators and the balance of plant are established via the in-house Intranet. Live data from a running technology system for immediate customer support and product lifecycle feedback provides a significant benefit for operation, research and development. Remote online diagnostics serves as the feedback loop into customer service, engineering and research & development after erection and commissioning.
Through remote access, the local diagnostic systems connected to RPGDC will send data via data containers. From the RPGDC the experts are able to assist in any critical situation which needs their immediate attention during commissioning or service. Just a few mouse clicks and they have access to data from power generating equipment from all over the world. It is important to receive continuous live data feedback from "running technological systems" at early stage, both for: immediate customer support: and product feedback.

Plant-wide Computerized Maintenance Management System (CMMS): as cost reduction tool

The increasing competition in power markets is making cost-optimized power plant management indispensable. A significant cost factor is labour cost for plant staff; it is considered that 20% to 40% of the working hours are spent for finding, compiling and archiving information (Illbruck, 2003). The process includes: Recording and maintenance of plant documentation; Provision of information on present plant's conditions; Monitoring of defects, failures and their follow up; Prepare, issue and expedite orders for spare parts, material and services; Cost control for spare parts, material and services; Process Work Orders generated by the work order management system; Control and follow up of de-energizing processes of related systems; Scheduling and Follow Up of plant outages; and Management of spare parts inventory.

The preferred solution is an intelligent, plant-wide Information Technology (IT)-support in the form of CMMS; in particular for maintenance work, modifications, documentation and spare parts management. The experiences of O&Ms show that the workload for information management can be limited to about 10% of the daily working hours, with the help of IT solutions readily available for CMMS. The functions offered should be in line with standard power plant practices (i.e. extensive adaptation is not necessary), and special needs can be readily integrated as required. The system is delivered in a reconfigured form with power-plant specific catalogues which consider the fleet experiences also derived from utilizing the fleet data storage collected through applied OEM and O&M systems. All this ensures fast, smooth integration and high acceptance. The standardized hardware and software environment in place in the

power plants and RPGDC can also contribute to the field-proven interfaces features to other systems such as: Distributed Control Systems (DCS); I&C; Spares; Ordering System; and electronic documentation. This minimizes client's initial investments and ensures consistent, efficient processes. It can offer its users a 3 in 1 solution covering operation, maintenance and administration processes from fault detection, through permit to work establishment up to spares cost control and inventory management. A parameter to measure the stability of processes at a power plant is the downtime for major overhauls (Taud & Scheidel, 2004).

O&M Contracts with world leaders in turbine manufacturing brings: experience of O&M of that organization; Long Term Maintenance contracts experience; and a knowledge network sharing all relevant technical information through their home based back office. The knowhow of the Customer together with the O&M contractor's experience ensures maximum long term asset protection. The contribution of the customer is the knowhow in regard to the regional power production requirements, and the long term experience in the local market pertaining to the power plant ownership. On the other hand, worldwide long term O&M experience is brought in by companies like; GE, Siemens, Toshiba, and Westinghouse etc. These synergy contributions from both parties allow a quicker elaboration of the O&M procedures and installation of the emanating engineering and administration processes.

Online Plant Thermodynamics benefits include: Identical thermodynamics code for plant design and online monitoring provides highest accuracy due to applied OEM knowledge; Online Thermodynamics detects decreases in performance of plant components (failures, degradation) as also drifting measurements, which can have an impact on operation due to I&C settings; Advantages for understaffed plants remote performance evaluations are offered by OEM's highly trained specialists.

OEM support advantages include: Early detection of abnormal operation remote diagnostics is more sensitive than equipment protection criteria/thresholds of I&C; profound root cause analysis by applying the entire knowledge of OEM; Continuous Monitoring gives Customer more security for further operation (Illbruck, 2003). In several cases it is possible to run the faulty equipment under close observation until the next planned outage. With timely repair planning by early fault detection and continuous remote monitoring, it is possible to optimize the repair process as it can be planned ahead and spare parts can be shipped in advance; Day analysis of unit data utilizing diagnostic tools can identify problems before they become critical. First Class Power Operation by ISO 9001 ensures comparison with global competitors. Transparent processes give common goals and motivation to the staff and living these processes means maximum control of the technical and financial aspects of plant operation to ensure: Maximum Plant Availability; Maximum Plant Profitability; Positive Public Perception; and Maximum Staff Motivation.

High-Pressure Boilers with Backpressure Turbine for Cost-Effective Power Generation

As the older base load units have to cycle, that creates higher stresses to the materials; they are no longer deemed proficient for the 21st century power generation operations. Therefore, when specifying a new boiler, consider a high-pressure boiler with a backpressure steam turbine-generator placed between the boiler and the steam distribution network. A turbine-generator can often produce enough electricity to justify the capital cost of purchasing the higher-pressure boiler and the turbine-generator. Since boiler fuel usage per unit of steam production increases with boiler pressure, facilities often install boilers that produce steam at the lowest pressure consistent with end use and distribution requirements. In the backpressure turbine configuration, the turbine does not consume steam. Instead, it simply reduces the pressure and energy content of steam that is subsequently exhausted into the process header. In essence, the turbo-generator serves the same steam function as a pressure-reducing valve (PRV)—it reduces steam pressure—but uses the pressure drop to produce highly valued electricity in addition to the low-pressure steam. Shaft power is produced when a nozzle directs jets of high-pressure steam against the blades of the turbine's rotor. The rotor is attached to a shaft that is coupled to an electrical generator.

The capital cost of a back-pressure turbo-generator complete with electrical switchgear varies from about $900 per kilowatt (kW) for a small system (150 kW) to less than $200/kW for a larger system (>2,000 kW). Installation costs vary, depending upon piping and wiring runs, but they typically average 75% of equipment costs. Packaged or "off-the-shelf" backpressure turbo-generators are now available in ratings as low as 50 kW. Backpressure turbo-generators should be considered when a boiler has steam flows of at least 3,000 pounds per hour (lb/hr), and when the steam pressure drop between the boiler and the distribution network is at least 100 pounds per square inch gauge (psig). The backpressure turbine is generally installed in parallel with a PRV, to ensure that periodic turbine-generator maintenance does not interfere with plant thermal deliveries. In a backpressure steam turbine, energy from high-pressure inlet steam is efficiently converted into electricity, and low-pressure exhaust steam is provided to a plant process. The turbine exhaust steam has a lower temperature than the superheated steam created when pressure is reduced through a PRV. In order to make up for this heat or enthalpy loss and meet process energy requirements, steam plants with backpressure turbine installations must increase their boiler steam throughput (typically by 5% to 7%). Every Btu that is recovered as high-value electricity is replaced with an equivalent Btu of heat for downstream processes (USDOE, 2006)

CONCLUSION

Due to the changing market conditions all over the world the traditional way of handling the maintenance business does no longer fit these new environmental requirements. The solution is to achieve a flexible and short termed outage planning process and a reduction of marginal and transactional costs. RPGDC along strategic alliances with OEM and O&M service providers can fulfil all these demands through tailor made solutions based on long term contracts designed to leave the transactional business behind. The range of these strategic alliances may vary from operating plant service agreements to long term programs and O&M contracts with risk sharing elements and the possibility of complete outsourcing of the maintenance tasks. Value based and success oriented payment modules will make sure that both partners will benefit from a good performance.

Monitoring and diagnostics is a rapidly evolving field in power generation. The combination of available on-line expertise and strategic alliances provides cost-efficient service and benefits to the customer. For the customer, it is important in any given situation to have access to the knowledge of the people who designed their equipment. For the equipment supplier, the greatest benefit is to have live feedback from its own "running technological systems" that enables service provider to optimize its learning; and last but not least, on-line diagnostics and strategic alliances pave the way from scheduled maintenance to condition-based maintenance, thus helping customers to operate their units at maximum profit.

OEM and O&M suppliers provide solutions based on decades of experience; they are on the leading edge of technology in designing and manufacturing a wide range of equipment of power plants from steam turbines to I&C systems. Their full capability for engineering, design, procurement, manufacturing, construction and commissioning of a full range of power plants renders them the capability to handle complete turn-key projects. The in-depth knowledge of OEM and O&M suppliers in the design and maintenance of the power generating systems ensures a comprehensive and efficiently integrated *e*-maintenance result; a strategy that does not use excess spare parts.

RPGDC will provide comprehensive solutions from field sensors/actuators to IT systems. This is a generic *e*-maintenance system primarily designed for palm oil mills: however, it can easily be adapted to other capital intensive industries such as 'Automotive' for *e*-maintenance of their expensive equipment such as; stamping presses, and robotic welding & assembly units.

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