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ELECTRIC POWER SUPPLY IN AN OFFSHORE OIL PRODUCTION PLATFORM - A REVIEW

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ABSTRACT

A study of the provision of electric power using associated natural gas as primary source of energy, in an offshore oil production platform has been carried out. Some of the problems to be contended with include: the effects of impurities contained in the fuel gas supply;variations in the production process characteristics; space constraints and the fire hazards that exist in an oil production environment. The study revealed that power supply can be improved by modifying fuel gas supply manifold, and also by introducing multiple stage gas filteration units and neutralizer filter units. Finally, among other recommendations, it will be desirable to replace the battery-powered UPS system with a rotary engine UPS which can provide long-term power supply back-up as well as the benefits of rotating machines.

KEY WORDS: Offshore, Platform, Power Supply, Gas turbine, Rotary Diesel UPS.

INTRODUCTION

The terrain in the swamp and offshore environment make the installation of power transmission lines and switchgears difficult. Consequently, the connection of individual oil platforms to national grid is almost practically impossible. The problem is further compounded by the fact that most of these platforms are separated by long distances. It is therefore, more cost-effective to generate power for local consumption at each of these platforms.

Furthermore, because of the sensitive nature of the electrical loads on these platforms, it will not be a good economic decision to use a power source that is not very reliable. The production and transportation of crude oil is a continuous process and any unplanned outage will be disastrous.

Finally, the attraction for this independent power production stems from the fact that the primary fuel for the generator is gas which is readily available at any platform. Infact the gas hitherto was being flared. Also the use of natural gas has a few advantages, namely:

- it has a high capacity for preventing pinging in the engine.
- combustion is clean
- gas engines are easy to start; they have simple carburetion, simple fuel and crude oil filtering arrangement.
- there is no need for storage tanks since the gas goes straight from production to the gas engine. The excess will still be flared.

However, there are two major disadvantages in the use of natural gas and they are:

* inconsistency in heat value and impurities because the make-up of the natural gas depends upon the source and location.
* the fire hazard arising from the use of volatile and combustible material.

It is also necessary at this stage to mention that the use of the gas engine generator is only possible with the station running and producing fuel gas at adequate pressure. A diesel engine generator is therefore used for the initial start-up (black start). This set also serves as a stand-by or back-up in case of emergency.

POWER SYSTEM LAYOUT IN AN OFFSHORE OIL PRODUCTION PLATFORM

The basic features of the power system in an oil platform are shown in fig.. 1. There is the (main) gas turbine generator, then a diesel engine generator, and several UPS modules attached to some critical equipment (not shown in fig. 1. Because of space). The gas turbine feeds a high voltage bus bar which in turn feeds another bus bar (low voltage) via a transformer.

The diesel engine generator feeds directly into the low voltage bus bar. Recall that this diesel engine serves as back-up and is used also for the initial start-up of the facility and re-starting after a shut down. The diesel engine has a battery system for starting and a flame arrestor is attached to the diesel tank local vent.

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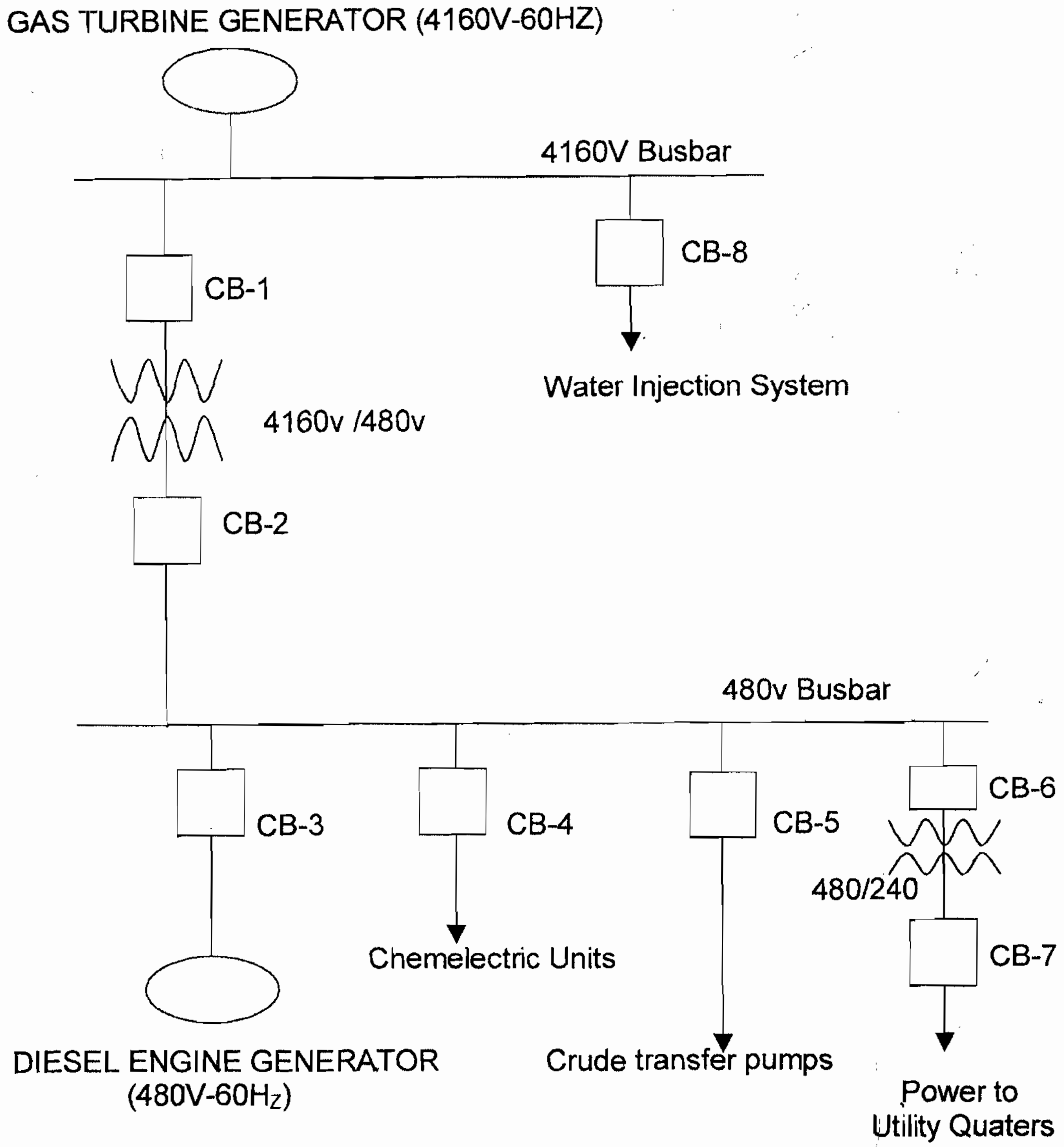

Figure: Typical Platform Power System Layout

The gas turbine prime movers are high in initial cost and fuel consumption but have a high power to weight ratio [1]. In a small platform with no water injection and gas compression facility, a smaller gas engine generator takes the place of the gas turbine.

Fuel Gas Unit

Natural gas associated with crude oil is separated from the crude oil in production vessels in the platform. Part of the gas is conditioned and used as fuel in the gas engine generation. Usually the gas is passed through special gas unit consisting of a scrubber and filters to remove scale, rust, dirt, and at times sulphur (see fig 2.).

The Ups

The uninterrupted Power Supply (UPS) is a bank of batteries arranged to supply emergency power in the event that both the gas and diesel generators are out of service. It is meant to supply power to the critical lighting, communication and safety systems on the platform. The UPS come in modules and are located near the load it is meant to supply.

The Air Compressor Unit

The air compressor is used in conjunction with an arrangement of suitable scrubbler, filters, dryers, regulators and valves to supply clear and water-free air for satisfactory starter operation.

Also the air compressor provides regulated instrument air for the pneumatic controllers, alternators and valves used for the control of pressure and liquid levels in the process vessels. The pneumatic control panels are supplied from the air compressor output.

The Motor Control Centre

The motor control centre (the MCC room) is the main control centre. All local panels, master control panel, and safety system panel have their switchgears in the MCC room. The centre also has a digital control system from which the system status can be monitored.

PROBLEMS ASSOCIATED WITH PLATFORM POWER SUPPLY SYSTEM

In a typical oil production platform equipped with gas powered generator, so many factors can pose serious threat to smooth running of the power system if not properly handled. Some of these factors are:

Variations in Process Characteristics

Typical process variables in an oil production facility include pressure, temperature, liquid level and flow-rate. In the gas engine generator set, the prime mover controls include control for energy supply system variables such as fuel gas pressure and flow. Typical fuel gas pressure range is 100 – 140 psi. Since the fuel gas system feeds on the gas output of the production vessels, the adequacy of the fuel supply pressure is dependent on the stability of the production process. Though the vessel pressure is controlled within a desired limit, occasional variations beyond the control limits is experienced hence the fuel gas pressure is also subject to variation without warning. Such wide

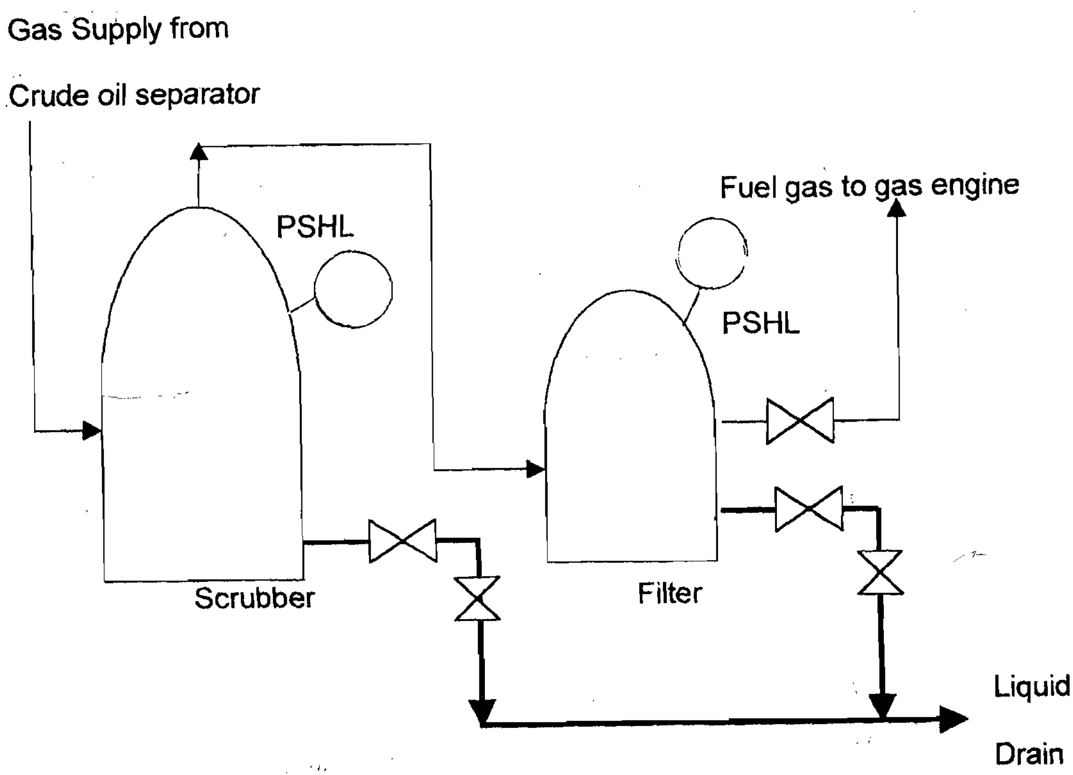

Figure 2: Fuel Gas Unit

variations, especially on the low side, if sustained, are a precursor to generator failure due to low fuel gas pressure. Also, system upset may lead to liquid level above normal operating level in the vessel, otherwise known as 'high level'. The worst case of this is "liquid overflow", a condition whereby liquid is discharged through gas outlet. This could lead to liquid carry-over to the fuel gas scrubber and filters. Depending on the efficiency of the fuel gas system, fuel gas with unacceptable percentage of liquid content could have an impact on the gas generator which would invariably impact negatively on its smooth operation and efficiency. Furthermore, the formation of condensate along fuel gas and starter air lines (function of operating pressure are restrictions/bends) impact negatively on system performance.

Presence of Impurities in Fuel Gas Feed

Due to the limitations of the scrubber and filters of the field installed fuel gas system, impurities like scale, rust and dirt, in addition to entrained liquid contaminants, are present in fuel gas stream. In addition, depending on the source of gas and the characteristics of the producing reservoir/formation some mineral compounds that do not promote gas engine efficiency are present in the fuel gas. For example, the presence of sulphur in the well fluid leads to the precipitation of sulphur compounds which may gain access into the gas engine. These and entrained oil form sticky deposit on vital parts of the engine over a period of time, especially when the generator is out of service (on stand-by) for a prolonged period of time. Inability to start-up smoothly, increased wear and failure are consequences of such impurities.

Cumbersome Power Change-Over Process

A typical production platform has at least two generators; one serving as standby. Changeover from one generator to the other is mostly achieved either by completely shutting down one in order to bring the other on line, or by synchronization (on-line). Some configurations without means of synchronization have multiple and cumbersome processes that cause undue delays in the name of protection. This sometimes leads to power outages for periods long enough to cause platform upset and shutdown. This is mostly so for stations that employ mainly electric drive systems (and this is the trend) as opposed to pneumatic drive, including pipeline pumps which need electricity supply to function.

Adverse Weather Conditions

Pre-lube is an important process in engine start-up cycle. Quite often this process is impaired especially during cold weather conditions and after a long period of non-service. This usually results from low oil temperature leading to increased resistance to flow. Though in some instances cranking the engine repeatedly is helpful, a scenario of multiple upset, including low fuel gas and/or starter air pressure underscores the essence of reliability and availability of stand-by generators. Also, persistent wind direction against the generator radiator/heat exchanger impedes heat dissipation and consequently, a build up of engine temperature that is capable of shutting down the generator.

Inadequate Operator's Experience

As in many other engineering set-ups' it is not surprising that the legendary maintenance and operating manual furnished by equipment manufacturers and the catalogue of company policies/standard operating procedures fall short of providing the solution for a platform power supply system that can, all alone, pass the practical test of continuity, stability and reliability. Although the overall system basically relies on many different types of telemetering and control signals, the operator is an indispensable link at various levels as he manages resources, co-ordinates related information from diverse sources, and adopts corrective strategies to maintain the system at a secure state of operation. Consequently an invariable guarantee for a secure system is the level of expertise the operator brings to bear on the job. This human factor, manifesting in various dimensions accounts for many shortfalls of a reliable platform power supply system.

PLATFORM POWER SUPPLY MANAGEMENT SYSTEM

The oil production platform is designed to operate continuously, day and night, for years with diverse electrical equipment performing critical functions in the production process. The situation demands a reliable good quality electric power supply (good quality means constant voltage and frequency). For purposes of maintaining the integrity of the entire power supply system, its reliability embraces the reliabilities of the sub-systems and components, namely, the generator, fuel gas unit, air compressor, etc. Therefore, any program aimed at ensuring the reliability of the system should involve these individual sub-systems at all levels. Let us briefly look at six strategies of maintaining reliable power supply.

Provision of Alternate Gas Supply Manifold

For stations that have two or more vessels operating at pressures adequate for supplying gas to the fuel gas scrubber, a manifold equipped with a divert valve should be provided to permit independent gas supply from the vessels. For purpose of switching and control, the divert valve is activated by a relay that responds to an undesirable condition in the vessels, namely, high level and low pressure conditions. This gas supply strategy enhances the advantage of using produced gas as the primary source of energy as well as reduces the susceptibility of the fuel gas system to malfunctions resulting from undesirable events in the production process. Consequently, the gas engine generator and indeed the power supply system is relieved of process induced inefficiencies.

Multi-stage Filtration

This is a process of passing the fuel gas stream through two or more filters in the fuel gas unit instead of one. By this, the quality of fuel gas is improved by eliminating both solid and liquid (entrained oil) impurities. Where analysis of the well fluid reveals the presence of minerals like sulphur and/or its compounds, a neutralizer filter should be installed to remove water and neutralize the sulphur compound(s). This helps to check wear and degradation of engine components resulting from chemical attack. It is also advisable to install auto drains along the fuel gas line as a means of eliminating the condensate formed along the lines. In the absence of this, manual valves can also be provided and the line is bled down as frequently as is necessary to maintain dry gas. In the case of air compressor, multiple dryers connected in series may also be installed downstream of the compressor to improve air supply quality. Auto and manual drains when used in conjunction with the liquid control valve, also prove to be helpful.

Development of Standard Operating Procedures (SOP)

Standard operating procedures communicate policies, procedures and programs developed by an organisation/company for the purpose of establishing basic guidance for standardizing specific operations. Suffice it to say that while a general SOP could serve as a model for a company, each department would need to generate its own SOP for specific assignments. The need for this is a consequence of different processes, safety requirements, expertise, details and possible authorization needed to perform a specific function. A faithful implementation of the SOP will give general and specific guidance for the operation of a facility as well as each equipment on board including those of the power system. For example different SOP will be needed for

(a) Start-up procedure for a fuel gas system
(b) Start-up procedure for a generator (gas and diesel)
(c) Power changeover procedures for (a), after power failure and (b), on-line i.e. synchronization of two sources.

The publication and conscientious application of SOP eliminates confusion and indecision among operators as well as creates a culture of respect for procedures. Apart from start-up and operating procedures, such other activities necessary to ensure a secure system are highlighted. For example, it may be required that all standby engines including generators, should be started every 48 hours to minimise the incidence of pre-lube failure [2] due to extreme weather conditions.

Personnel Training and Empowerment

Training and re-training of personnel is critical to effective performance of duties. This is more so in the light of the dynamic nature of oil production operations; increased automation of processes and controls techniques, new technologies that necessitate acquisition of new skills, implementation of new regulatory policy, etc. In addition, personnel training is to be appreciated as a means of empowering operators to take decisions as situation may demand, such as in an emergency. For example, an oil production platform operator who finds a situation that poses a threat to the environment (risk of pollution) is expected to take necessary steps to avert it, which may include partial/total platform shutdown. The only guarantee that he can carry out this function effectively with minimum hesitation is that he is adequately empowered through training and experience. In this connection, it must be mentioned that a safety equipment or other equipment is never really available until the intended user(s) can boast of using it effectively when the situation demands.

Development of Good Maintenance Policy/plan

Generally, generator packages supplied by manufacturers are equipped with gauge panels for monitoring the system status, for example, lubricating oil pressure, jacket water temperature, under and over frequency, engine speed, etc. Provisions are also made for making necessary inputs for control of operations, e.g speed/frequency and voltage adjustment as well as specification of spare parts, type and grade of lubricating oil and fuel, type of filters, care of radiators or heat exchangers, etc. These recommendations, if adhered to, ensures the machine is in good order and operates reliably. However, because of the varying degrees of mechanical, electrical, thermal and environmental stress that the machines are exposed to, most companies generate a maintenance programme, invariably built around the manufacturers recommendations, which include daily, weekly, monthly, etc checks and tests. Generally, these maintenance programmes are preventive/predictive in nature and should not exclude preparedness for occasional corrective maintenance actions.

Diesel Engine Ups Power Solution

The diesel engine UPS power solution for oil production platforms is essentially a rotary UPS which, instead of using a bank of batteries as the short term energy store, uses a form of kinetic energy storage and an integral diesel engine. This unit provides uninterrupted power by utilizing the kinetic energy store for short durations and the diesel engine for long term energy supply [3], [4].

The diesel engine drives the inner rotor at a speed of approximately 1540 rev/min. A dc supply to the outer part of the coupling transfers the energy by means of the breaking action, to the outer part and hence to the synchronous alternator. The frequency of the outer part is independent of the speed variation of the diesel engine, provided the engine runs above a minimum speed. The control circuit adjusts the dc supplied to the induction coupling and maintains the output frequency within tolerance. In this condition the UPS can run as an autonomous unit, assuming the role of emergency standby generator.

The UPS generates its own power during mains interruptions, and therefore, when the mains is restored, there is likely to be a situation where the two supplies will not be in phase. A paralleling check device senses this condition and waits until the vector systems are coincident before commanding the mains connector to close.

The outer part of the induction coupling is energized with an ac supply and the inner rotor accelerates. At a speed of 1600 rev/min, the free-wheel clutch disengages and the inner rotor continues to accelerate up to full speed. At full speed the rotor contains sufficient stored energy to deal with the next mains irregularity. After a period of approximately three minutes, the diesel engine is switched off.

CONCLUSION

The unique features of electric power supply system in an offshore oil production platform have been analysed. The problems associated with this independent power generation include the variation in process characteristics like gas pressure, high liquid level, etc; the presence of impurities in fuel gas infeed; adverse weather conditions; and inadequate operator's experience.

The study further revealed that the following strategies can address the problems listed satisfactorily. They are: the provision of alternate gas supply manifold; the adoption of multistage filtration; the development of standard operating procedures; personnel training and empowerment; the development of good maintenance policy; and finally the introduction of diesel engine UPS to take care of unexpected long duration power outage from the gas turbine.

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