Return to Session Directory

DYNAMIC POSITIONING CONFERENCE
October 9-10, 2007

Risk

The Road to Eliminating Operator Related Dynamic Positioning Incidents

Arjen Tjallema

Clemens van der Nat

Bluewater Energy Services BV

Hugo Grimmelius

Douwe Stapersma

Delft University of Technology

MTS Dynamic Positioning Conference, Houston 2007

The Road to Eliminating Operator Related Dynamic Positioning Incidents

Arjen Tjallema, arjen.tjallema@bluewater.com, Bluewater Energy Services BV
Hugo Grimmelius, h.t.grimmelius@tudelft.nl, Delft University of Technology
Clemens van der Nat, clemens.vandernat@bluewater.com, Bluewater Energy Services BV
Douwe Stapersma, d.stapersma@tudelft.nl, Delft University of Technology

Abstract

The history of Dynamic Positioning shows that in most incidents the DP operator is involved. Reducing the amount of operator related DP incidents could therefore significantly increase the safety and reliability of DP operations. An operator's workload during DP operations seems to be the most important cause of operator errors. By splitting DP operations into three different operational modes this workload problem could be resolved such that the operator's performance will improve. To allow for this split in operational modes a self-diagnostics system and an operator support function should be added to a DP system. This paper will describe the problem of operator related incidents, the split into three operational modes and the function of a self-diagnostics system and operator support function.

Introduction: Dynamic Positioning Incidents

Dynamic Positioning (DP) operations have been performed since the early 1960s, when the first DP drill ships were deployed. During the more than 40 years of DP operations, much is learned on the nature of the operations and their risks. Recently a DP incident analysis [IMCA, 2006] has been published, which shows the causes of DP incidents that are reported over a period of ten years. Fig. 1 shows a summary of the findings in that report. The *Loss of Position Incidents* shown are split up in *Major loss of position* and *Minor loss of position*, as shown in the figure.

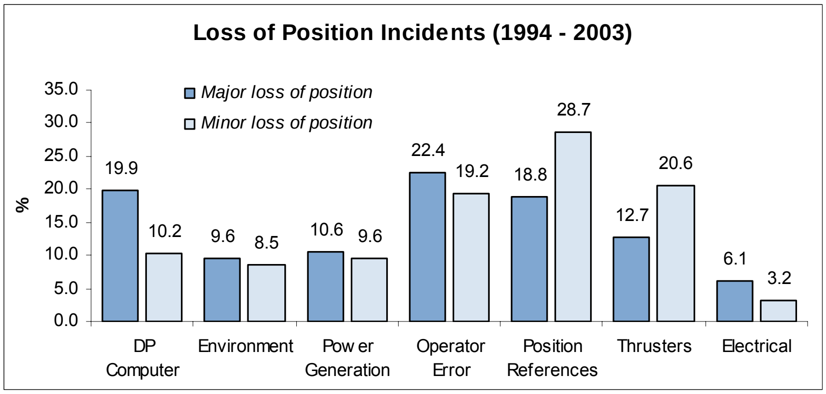

Fig. 1 - DP incident causes

The DP incident data shows that DP operators cannot prevent a substantial part of DP incidents, for *major loss of position* incidents operator errors are even the most important cause. Because the DP operator can influence the complete DP system, an error can have considerable effects. An operator error could therefore unfortunately be considered as a worst-case single point failure in the DP system.

In a great number of (near) DP incidents, the operator can be found somewhere in the event chain. This can either be at the beginning, when the operator initiated the event, or somewhere in between, where the operator makes an unfortunate decision and/or is not able to find the root cause of a fault in time.

The large number of operator errors in DP incidents means that reducing the amount of operator related DP incidents could significantly increase the safety and reliability of DP operations. This paper will describe how operator related DP incidents can be reduced and eventually even could be eliminated. A fault that initiates a DP incident can be a failing component in the DP system, an operator error, or anything else that could possibly harm the system’s position keeping ability. After initiation of such a fault, the DP system will go through an incident process as described in the following section.

Incident process

After initiation of a fault, a DP system and its operator will go through an incident process, which is split into five consecutive phases. Fig. 2 shows a timeline on which the phases of an incident are schematically drawn. The vertical axis in this figure shows the workload of the DP operator, which has a sudden rise when a fault is detected. The workload curve as shown in this figure gives an indication of what happens in an emergency situation, it is not meant to give an exact representation of the workload.

The figure shows two key parameters in the incident process: the available time and the time that is needed to detect and solve or isolate a problem. In a black-out event for example, the time that it takes for the environment to drift the vessel to the limit of the watch-circle is the available time. In this example, the time that starting up power generation and thrusters takes to regain station keeping ability is the time needed to solve this problem. When the time needed to solve a problem is longer than the available time an incident will happen, otherwise an incident is prevented.

The latter will obviously be the desired situation. The chance of preventing a fault from resulting in an incident can be increased by either stretching the available time or by shortening the time needed to solve a problem. Stretching the time could for instance be done by changing operational procedures, for example: choosing a position in the watch-circle such that the time to reach the circle’s limit after a drift-off is maximized. The time available for solving a problem will of course strongly depend on the nature of the fault that occurred. Increasing the available time will not be within the scope of this paper; the focus will be on shortening the time that is needed to solve a problem.

Shortening the time that solving a problem takes can be done by shortening any, or preferably all, of the five phases in the process: *detection*, *fault identification*, *generation of solution strategy*, *solution implementation* and *system’s reaction* on this implemented action. The operator has a big influence on the time that is needed to solve a problem, as he has to perform at least three of the five phases: *fault identification*, *generation of a solution strategy* and *implementation of the solution strategy*. The detection of a fault is done by either the DP system or the operator and the reaction of the system on an implemented solution strategy is obviously done by the system itself. The following section will explore the role that the operator plays in the DP system and especially his involvement in the incident process.

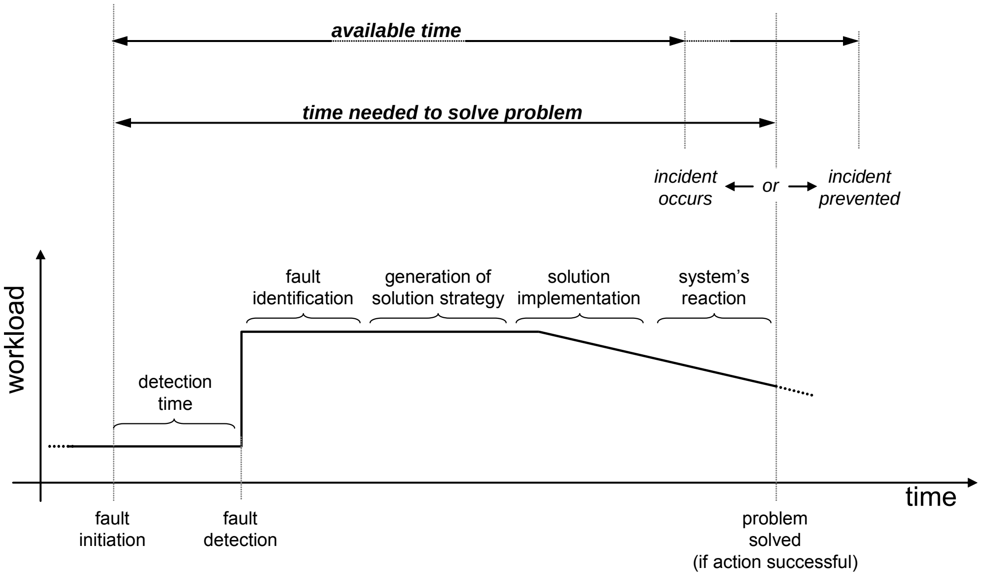

Fig. 2 - Phases in DP incidents (workload indicative)

The operator's role

The role of the DP operator is mainly influenced by the design of the DP system: the automation in the system and its level of autonomy determine the work that is required from the operator. In this section some aspects of the operator's functioning will be described.

Level of automation

The development of DP technology in the past decades has changed the role of operators, due to a steady increase in the level of automation. This shifted the tasks of the DP operator into a more and more passive monitoring role, a task for which humans are not very well suited.

Due to this passive, monitoring task, the operator's 'situation-awareness' is often low. This is known as the 'out-of-the-loop' performance problem, as the operator is not an active part of the process, [Parasuraman, 1993]. The operator has no direct need to constantly know what the status of all parts of the DP system is, because the DP system is controlling all components itself. Only after a failure arises the operator needs to take over this task and take appropriate action(s) to prevent the failure from harming the operation, or abort the operation in time to prevent accidents. The low situation awareness due to a high level of automation makes that the operator cannot intervene quickly and effectively if the automation fails.

Failure experience

In the first DP operations in the 1960s, DP systems were non-redundant and reliability was very low. In the 1980s, when DP was being used more and more, an average loss of position rate of once every six months has been realized. Up to now the mean time between failures has been improved to about five years, by the application of redundancy and improved control algorithms, [Shatto, 1997]. The downside of this development is that a DP operator will in general have very little experience with real DP failures or emergencies. Despite DP training programs, the operator will not be well-trained for these possible events and will therefore loose valuable time recognizing the problem and solving it.

Reaction time

An investigation of [Chen & Moan, 2003] shows reaction time of DP operators in forward drive-off incidents on shuttle tankers, see Table 1. In this table three different times are shown:

- Recovery action time since drive-off initiation: in Fig. 2 this is the time from the fault initiation up to the start of implementation of a solution strategy
- Collision time since drive-off initiation: in Fig. 2 this is the time from the fault initiation up to the time where an incident occurs. In this case the time needed to solve the problem was longer than the available time, such that an incident happened.
- Stop time since drive-off initiation: this is the time from the fault initiation up to the time where an incident is prevented in Fig. 2. In this case the time needed to solve the problem was thus shorter than the available time.

The data in Table 1 show that in most cases the operator is not able to react fast enough after the initiation of a drive-off incident. The available time-window for reacting on such an event is in general very short, and the chances of preventing an accident decrease rapidly after the fault-initiation. The relatively slow reaction time indicates that either the fault detection is slow or the operator needs too much time to recognize the failure and to decide what action to take. This results in a long time (often too long) that is required to complete the first three phases of the problem solving process.

Table 1 - Operator reaction times

Collisions	Recovery action time since drive-off initiation (s)	Collision time since drive-off initiation (s)
1	close to 120	120
2	91	143
3	167	Not available
4	58	125
Near misses	Recovery action time since drive-off initiation (s)	Stop time since drive-off initiation (s)
1	45	140
2	very short	75

Workload

As described above, the role of a DP operator in day-to-day circumstances will be to passively monitor the system. The DP system will handle all tasks as long as no unexpected events occur. Especially for long-term stationary operations, this task makes the life of an operator not very exciting. Apart from some fine-tuning and minor adjustments, the operator will have nothing to do but verify that the system is working correctly. This situations leads to a potential threat on the system: as the operator will not be alert to respond adequately in case of a fault.

Once a fault occurs, the workload of the operator suddenly rises from very low to very high. After failure detection, the operator has to go through the four last phases of problem solving in a relatively short time to prevent an incident. This sudden increase in workload and the relatively high workload itself will not be beneficial for the operator's performance and will highly increase the chance of making wrong decisions.

Research of [Grootjen & Neerincx, 2005] shows that a non-optimal workload can highly deteriorate performance. In this research, a model is developed in which three parameters are used to determine workload: *number of task switches*, *time occupied* and *level of information processing*.

The percentage of time occupied is regularly used as a measure for workload, often based on the notion that people should not be occupied for more then about 80% of available time. When an operator has to switch between tasks, he has to start using different knowledge that is applicable to the new task. This switching between applicable knowledge will require human resources and thus increases workload. The level of information processing refers to a skill-rule-knowledge framework. In this framework at the skill-based level information is processed automatically and will thus hardly be cognitive demanding. On the rule-based level routine solutions are found for problems, by applying *'if <event/state> then <actions>'* rules. The knowledge-based level information is analysed to find an appropriate solution to a problem, which therefore will be the most demanding level of information processing.

A schematic representation of the model is shown in Fig. 3, where the arrows show the direction in which the values of the three parameters increase. The areas of *overload*, *underload* and *optimal workload* are indicated, as well as one other area where *vigilance problems* occur. These vigilance problems arise when an operator is continuously occupied, but he has to perform one task for which the level of information processing is low. In this situation routine and boredom lead to a lack of attention which will cause mistakes.

Non-optimal workload during DP operations therefore seems to play an important role as a cause of operator errors. Changing the role of the DP operator such that the workload is shifted towards a more optimal level might potentially be an effective means of reducing the amount of operator related DP incidents.

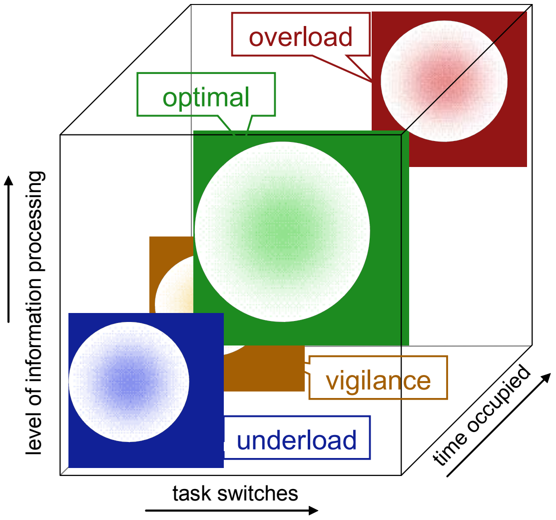

Fig. 3 – Workload model, [Grootjen & Neerincx, 2005]

Situation awareness

An operator monitors the DP process continuously during operations. The DP system is too complex to have a complete overview of what is happening in detail, so it is impossible for the operator to be aware of the exact status of all (sub-)systems all the time. This may cause a lack of situation awareness once a fault occurs. The operator will have to search through the system to find relevant details which provide input for his understanding of the fault and its root cause. This search process consumes a lot of valuable time in the problem solving process.

DP operating conditions

Non-optimal operator workload, either too high or too low, is expected to be an important cause of operator errors, as described above. In DP operations, three situations can be distinguished where the operator's workload is essentially different:

- **Normal operation.** In 'normal' conditions, the workload of the operator will be very low. The DP system will in general be able to work autonomously; the operator only has to monitor the process.
- **Alerted operation.** In some situations the operator will be more actively involved in the DP operation, for instance in DP shuttle tanker offloading operations. There will be more activity in the DP operation in these cases, and inherently this will increase the probability of faults. The operator will in this situation be actively involved in the DP process, as for instance the operational environment changes constantly such that the operator has to update the system's input accordingly. The probability for operator failures therefore reduces as he is alert and his workload can be considered 'normal'.
- **Emergency situation.** In emergencies the operator can easily become highly over loaded: a fault in the system has to be identified very quickly, such that appropriate actions can be taken to recover from the failure without (severe) consequences for the operation, or if this does not succeed the operation should be aborted in time to avoid consequential damage.

The way in which the DP system is operated should be different in the three situations to fit the expected workload of the operator. In the DP system three modes of operation will therefore be defined: *normal mode*, *alerted mode* and *emergency mode*. The DP control system and its interface should be designed such that the task of the operator better fits human abilities in each mode.

In Fig. 4 five levels of automation are shown, as defined by [Endsley, 1996]. The three operating conditions for the DP system are put on this scale, to visualize the division of workload between the operator and the DP computer. The three modes of operation are shown in the figure, on different levels of automation. The following sections describe the modes of operation in more detail.

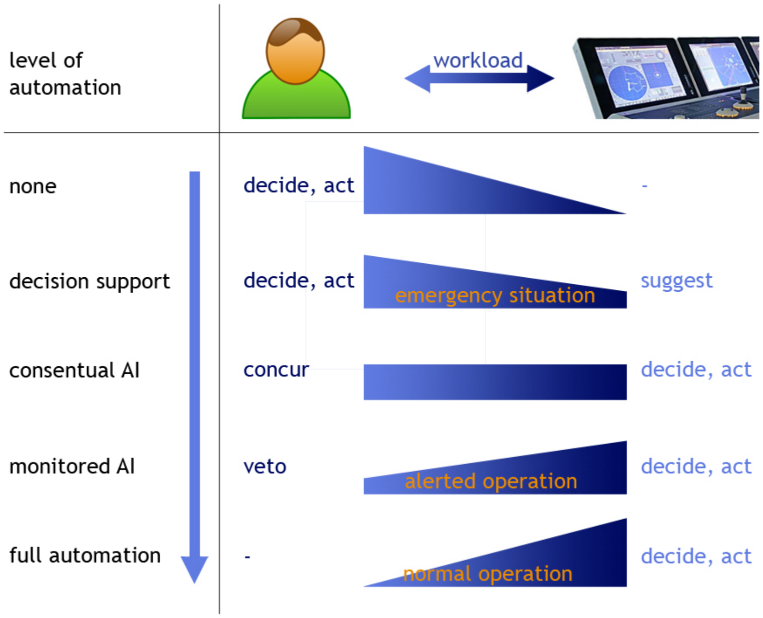

Fig. 4 – Levels of automation

Normal mode

When the DP system can operate on a very high level of autonomy and the operator only has to monitor the system passively, the operation can be considered to be 'normal'. Almost all of the work for running the DP system is done by the DP computer in this situation, which causes under load of the operator.

The split of work between the operator and the computer can however be changed. This can be used to influence the workload of the operator: when work is shifted from the operator to the computer, the operator's workload will decrease and vice versa. Artificially increasing the operator's workload, by shifting tasks that can be performed by the DP computer to the operator will be a possible method of increasing the operator's workload. This will however not really solve the problem, as the work that is done by the computer will be relatively simple and repetitive. When these tasks have to be done by the operator it is unlikely that his alertness will increase, as doing repetitive simple tasks will probably bore him as much as doing very little work ('vigilance' in the workload of Fig. 3). Shifting work from the computer to the operator will thus not be a satisfying solution for the low workload problem.

Although paradoxically at first sight, the solution to this problem could be found in further decreasing the workload by shifting work from the operator to the DP computer: if the operator's workload can be reduced to nil under normal operating conditions, the operator can perform other tasks on the ship as long as the DP system is capable to operate the system autonomously.

Allowing the DP operator to perform other tasks on the ship's bridge during the DP operation will make his workload go to a normal level. If his attention is required by the DP system he should immediately return to the DP operator consoles to familiarize himself with the system status to see what is going on. This requires an unambiguous user interface to present the system's status, such that the operator will get clear situation awareness in a very short time.

To allow the DP computer to operate completely autonomous, it will have to take over the monitoring task that is now performed by the operator. This means that a self-monitoring function has to be included in the system, which will detect any irregular behaviour in the DP system. Once an anomaly is detected, the monitoring function should trigger an alarm that calls the operator back to the DP station. The system then switches to *emergency mode*, which will be described below.

Calling the operator once a fault is detected implies that the operator is not allowed to be physically far away from the DP console. Due to the short response times of a DP system, the available time for solving a problem is still relatively short. Operating the DP system without continuous operator monitoring and where the operator will be called only when required, is called *unattended DP* (Fig. 5).

Whenever the DP system is not able to operate completely autonomous, for example when system behaves unexpectedly, but no fault is detected, or if the probability of a fault in the system is high, the system will switch to *alerted mode*. In this situation the operator will be operating the DP system, as described in the following section. This could for instance be done during offloading operations or during severe weather conditions.

Fig. 5 – 'Unattended DP'

Alerted mode

The alerted operation mode will be very similar to DP operations as they are currently done. The operator monitors the operation and adjusts parameters where necessary, to maximize the safety of the operation. The difference with a ‘normal’ operation as described in the previous section, is that the DP operation requires constant supervision and adjusting due to a higher risk caused for instance by another vessel or structure in the direct proximity of the DP vessel. Because the operator will be working in the loop of the DP system now and there is more activity in the DP operation, it is expected that his workload will not be too high or too low.

Emergency mode

At the moment a fault or suspect situation is detected in the DP system, either by the self-monitoring system or by the operator, the system switches to ‘emergency situation’ mode. In this mode the workload may become excessive, as all five phases of the problem solving process have to be performed in a very short time.

The first task of the DP system in this situation is to inform the operator on the status of the system and the nature of the fault that is detected. Especially if the system goes into ‘emergency’ mode after operating in ‘normal‘ mode, the operator has to be informed thoroughly, as he was not present at the DP system when the fault was detected.

To reduce the operator’s workload in the problem solving process, some of the tasks that have to be performed should be taken over by the DP computer. The four first phases of the problem solving process could in this way be done quicker, such that the chance of success is increased:

1. The fault detection phase will be taken over by the DP system completely, using a self-monitoring function in the system. This monitor should be able to detect faults much earlier than an operator, as the system can monitor all components of the system and can analyse trends simultaneously.
2. The fault identification phase might be integrated in the self-monitoring function. Once the self-monitoring function has detected the existence of a fault, the fault can immediately be analysed. The nature and root cause of the fault could in this way be determined much quicker than when the operator has to search through the system manually to find the cause of an alarm.
3. The generation of a solution strategy can be performed by the DP computer. A number of alternatives can be generated by the system. It could then run these scenarios in a simulation model to determine the effect of actions and advice the operator on the most effective ones. In this way the decision of the operator is supported by (numerical) action-effect evaluations.
4. The implementation of the selected action could be performed by the system itself. After presenting the options, the operator only has to approve the actions to be implemented and then monitor if the system’s reaction is as expected and the problem is indeed solved.
5. The system’s reaction on implementing actions will not be changed by this procedure, so the fifth phase will not be shortened. A diagnostic system can however be used to verify if the taken actions have the desired effects and, if not, adjust the actions to still obtain the desired effects.

In the third phase a decision support function needs to be added to the DP system to speed up the decision making process and to improve the quality of the decision. Relatively simple means of decision support already exist, for example in the form of ‘Well Specific Operation Guidelines’. These guidelines prescribe actions that have to be performed in some predefined events, [Adamson & Abrahamsen, 2006]. These support methods are however static and still require much effort and time from the operator. By implementing a support function in the diagnostic system, the support can be customized for specific situations, and advice can be generated and presented faster than with a static support method.

DP Self-Diagnosis

Operating the DP system in 'normal' mode as described above, requires the implementation of a self-diagnosis system in the DP system. This self-diagnosis system should perform fault detection and identification in the first and second phase of the incident process.

The general concept of a diagnostic system is presented in Fig. 6. The measured input signals to the process are used to generate reference values, which are compared with validated sensor readings from the plant's output, giving the residuals. Symptoms are derived in the health monitoring part. After the decision *healthy or not*, diagnosis is attempted using a knowledge database, which can be filled using different knowledge sources, such as simulation models, historical data, FMEA, expert opinions, etc. Basically, anything that contains information about the process that is monitored can be used as a knowledge source.

The monitoring and diagnostics system as shown in the figure can be applied to a complete system, or to individual subsystems. A combination is also possible, where the overall system is monitored and each subsystem has its own monitoring system. In this way a more detailed diagnosis could become possible.

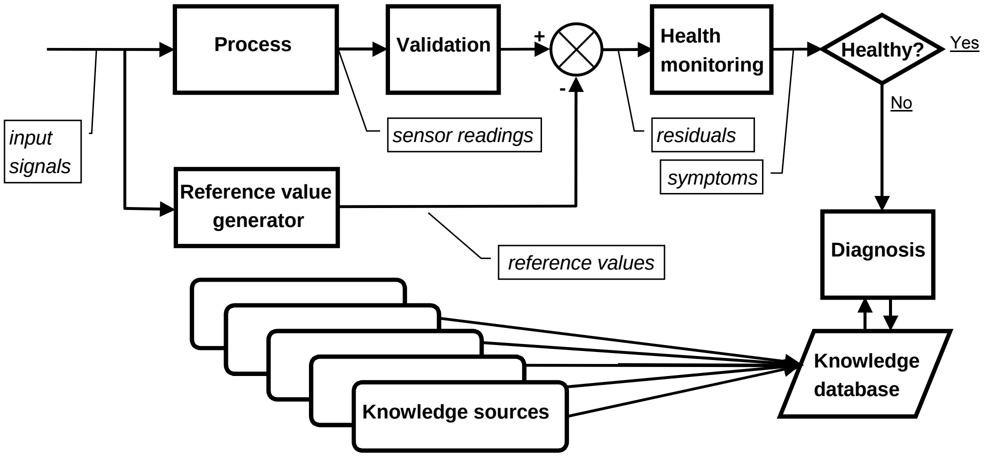

Fig. 6 – Terminology and structure for intelligent condition monitoring systems [Grimmelius, 2005]

Validation

The first step in monitoring input signals will be to check the validity of values for each individual sensor, for example by detecting freezing, jumps, etc. This will enable detection of some specific failure mechanisms of sensors. Drifting signals will however be unlikely to be detected in this way.

After checking the output of each individual sensor, the signals of a number of sensors can be checked for mutual consistency. If multiple sensors are available for measuring (strongly) related parameters, the sensors should give similar results. For example, the position as determined by a GPS system may for instance not differ (too much) from the position as determined by a hydro-acoustic positioning system. Some differences will always be present due to limited accuracy of the systems, so a threshold should be defined above which the difference between two sensors might indicate a sensor fault.

Health monitoring

After validation of sensor inputs, the signals will be compared to reference values that can be generated by models, as will be described in the next section. Due to modelling uncertainties and inaccuracies, the reference value will always deviate from the process, so the residual will not be exactly zero. Thresholds should therefore be determined above which the difference between model and process results will indicate a fault in the system. Fig. 7 shows an example of such a threshold for a process that is monitored. At the point where the residual runs out of the threshold bounds the system will detect a symptom of a possible fault, start the diagnosis and of course trigger an alarm.

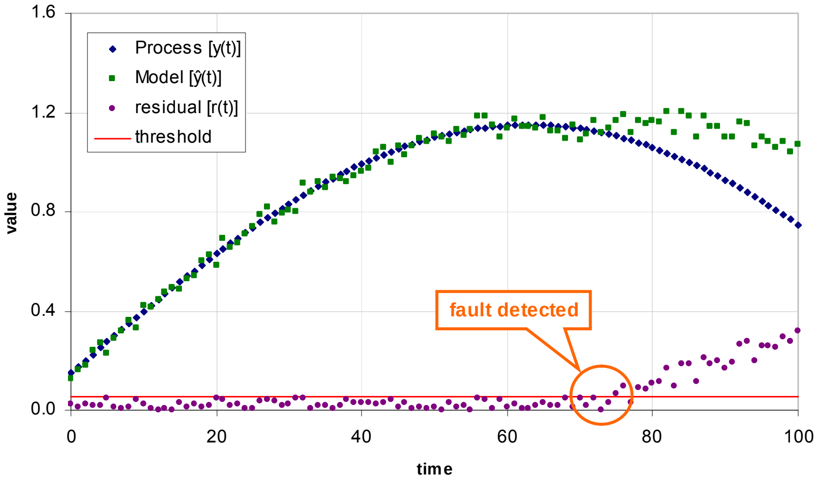

Fig. 7 - Threshold for fault detection

If the threshold is chosen high the system will be slow in detecting a fault, and thus loose valuable time for preventing an incident. If on the other hand the threshold is chosen too low a large number of false alarms will be given, which keeps the operator from doing other tasks and harms the credibility of the system. A safe threshold level should thus be found, at which faults will be detected in an early stage, but a limited number of false alarms is given.

Thresholds do not need to be static, as changing operational conditions can influence the performance of the monitoring system. In conditions where the monitoring system can accurately generate reference values the thresholds can be set at a lower level than in a situation where reference values are less accurate. The latter will however slow down the fault detection process. If reference values reach a certain level of inaccuracy, the system should decide to switch to *alerted mode*, because the detection of faults is expected to be too slow for safe *normal operation*. This could for instance happen in severe weather, because the hydrodynamic model in the monitoring system cannot accurately predict manoeuvring of the ship.

Reference value generation

As described above, sensors that measure the same parameters can be used to verify each other. Measurements from sensors that measure different parameters can be used for consistency verification too, when these parameters respond to a common cause. An indication for a fault in the vertical reference sensors could for instance be found if vertical vessel motions are measured to be high while the mean thrust level is relatively low, as both parameters respond to the wave conditions in which the vessel operates. In this way the sensors act as reference value generators for each other.

Once all sensor inputs have been validated, the system will use these inputs to generate control signals. This process should be monitored too, so a set of reference values should be generated to compare with internal parameters of this process. Both first-principle time domain techniques and black-box techniques, such as ANN, can be used for this purpose.

When first-principle time-domain knowledge is available this type of model will be the preferred technique, as such a model closely replicates the real process. A drawback will however be the accuracy of the model; uncertainties and simplifications in the model will introduce differences between the model and the real process. The larger these differences are, the larger the residual thresholds have to be set and the slower the system will detect a fault.

Using a black-box technique could decrease modelling errors. An ANN could for instance be trained to mimic the DP system's behaviour. As in such a black-box model no physical processes need to be modelled, but instead only a system's behaviour is imitated, no simplifications and assumptions are needed. The quality of the representative training set and the selection of the layers and type of neural functions will determine the accuracy of the results. From other research it is expected that lower thresholds can be allowed by using a black-box method instead of a first-principle modelling method, [Grimmelius et al, 1999].

The drawback of using a black-box model is that it does not provide a look inside the process, because usually only the behaviour of the complete system is modelled by using in- and output parameters values only. This will make fault identification of errors inside the system difficult. Furthermore, a neural network has to be trained with a large representative dataset. The process therefore has to be operated for a long time to collect sufficient representative data before the model can become functional. To overcome this, training data from a (different) numerical model is used, which also introduces modelling differences between model and reality.

Implementation of diagnostics

If a possible fault is detected in the health monitoring, a diagnosis is generated, based on the symptoms (detected residuals that exceed their threshold) and the knowledge in the database. For the diagnosis many methods are available. For instance a (fuzzy) rule based knowledge base might be used, containing rules in the form of: *if* vertical vessel motions are *high*, *then* mean thrust level should be *high too*. Also (fuzzy) pattern recognition can be applied to the *pattern* of symptoms. Also black-box approaches can be used, based on for example Artificial Neural Networks (ANN).

A possible implementation of the diagnostics for the DP system is schematically shown in Fig. 8. The values that are read by the sensors are checked for consistency, for each signal individually and for multiple signals together. The internal signals in the DP computer and the measured signals are verified with a set of reference values, which can be generated by a model. Both the consistency check and the model based verification can trigger an alarm to call the operator in case any suspect behaviour of the DP system is detected. Once the alarm is triggered, the system switches to *emergency mode* where the operator is supported in solving the problem by providing a diagnosis and relevant data.

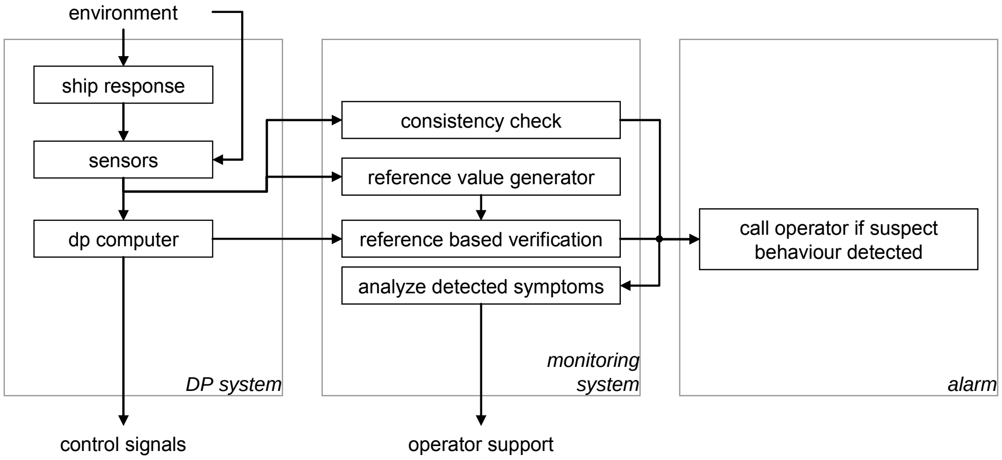

Fig. 8 – Monitoring system

A concept using various techniques combined is likely to provide the best results. For instance the reference value generator should be based on first principle techniques where possible. If not, a black-box method should be used to keep the residual threshold within acceptable limits. The diagnostic system could use a rule based approach for high level identification and for instance ANN for detailed (component) diagnostics.

Operator support

At the moment a fault is detected in the system, two steps should be taken: first the operator should be informed on the status of the system, secondly the operator should be supported in solving the problem that was found in the system, to prevent it from escalating to an incident.

Presentation of system status

Because the operator has not been monitoring the DP system during ‘normal’ operation, he will have to get awareness of the system’s status to be able to find the cause of a fault and solve a problem. Providing the operator with information on the system’s status will be a key factor in this way of operating a DP system: because the monitoring process is performed by the DP system itself, the operator will have to invest some of his time in getting informed. This will elongate the fault identification process, and thus the time needed to solve the problem (Fig. 2). The lost time should be made up by the fact that the operator will be more alert when he has been actively working on another task instead of passively monitoring the DP system. This will again shorten the identification process and the generation and implementation of a solution strategy.

The DP interface should provide the operator with all key information of the DP system, such as: vessel position and speed, available/consumed power, available thrusters, spare thrust available, etc. All this information should be provided in one clear view, such that the operator does not need to browse through all kinds of subsystems to gather information. The fault that has been found in the system should be presented simultaneously, together with potential causes of this fault. Further research to this familiarization process will point out what the most effective way of informing the operator will be.

Solving the detected problem

After informing the DP operator on the system's status, a solution strategy should be chosen to prevent the detected fault from causing an incident. If the root cause of the problem is not clear, the operator might need support to find this cause and take appropriate actions.

When a fault is present in the DP system, it will not always directly be clear what the effect of an action to arrest the fault will be. Simulation based techniques can provide clarity as the model includes the system's reaction time: an online simulation model can be used to simulate a number of possible scenarios to predict and evaluate the effect of certain actions.

Information that is found in the monitoring system should be passed on to the support function, such that the location and type of fault becomes known. In this support function, a number of strategies should be generated which might solve the (known) problem. These strategies could be generated by either the operator or the system itself. The generated strategies then must be analysed to determine what their effect on the system will be, for instance by simulating the implementation of a strategy in a model of the DP system. The model should simulate the DP system for some period in the near future using the actual status as initial values.

Based on the simulation results, the system should present the strategies that are found to be able to prevent an incident to the operator, and propose which one will be most effective.

The operator support function might be able to further help the operator. Once a fault is detected, it could for instance give the power management system a command to start up al generators, such that the maximum amount of power is available. The generators should not be connected to a switchboard automatically, because connecting the wrong generator could cause a black-out. Research should point out which actions could be safely performed by the support system to assist the operator, and which actions should be confirmed by the operator before they are taken.

Adding new functions to a DP system

The structure of the complete DP system with diagnostic and operator support module can be designed as shown in Fig. 9. In this way the new modules are connected as an add-on to an existing system, which in this way will keep its integrity. Once the system has proven to be successful it can be fully integrated to DP systems.

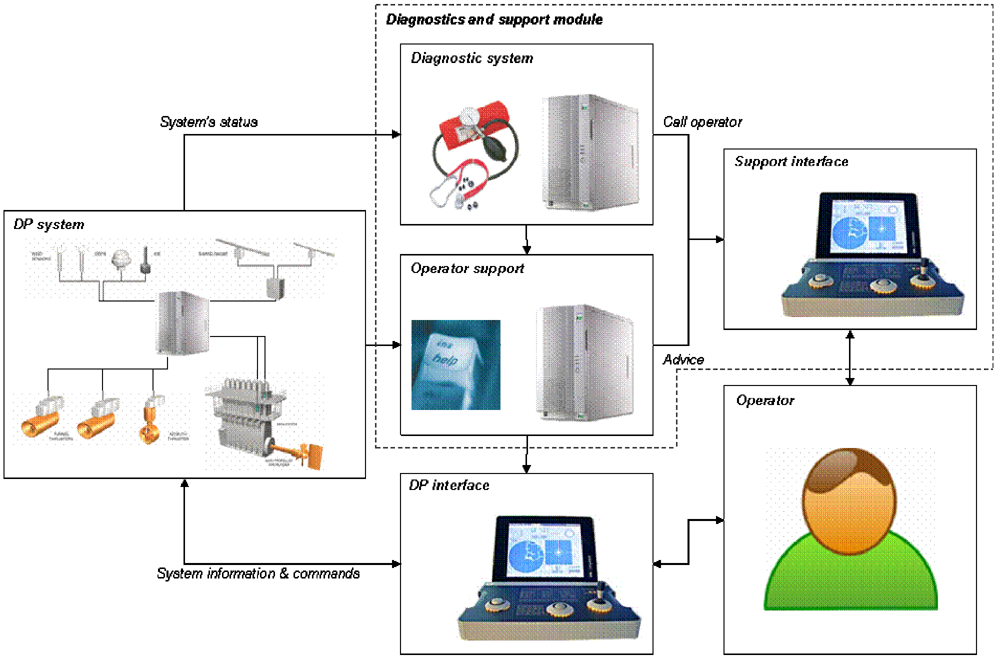

Fig. 9 - DP system with diagnostic and support function

Requirements and risks

The most important issue to be resolved for safe unattended DP operation is the assurance that the operator will be called in case of any fault/irregularity in the DP system or operation. The DP system should recognize when the operator will be needed to return to the DP control station as early as possible. A pitfall will be that a too strict policy will lead to many false alarms, which will harm the system's credibility and will not allow the operator to perform other tasks efficiently.

Once the operator is back at the DP system, he will quickly have to familiarize himself with the actual status of the system. The DP system should support this familiarization process, to shorten the required time as much as possible. Understanding the operator's familiarization process and an effective and efficient interface to support this process should be included in the system.

In the model that will be used for diagnosis of the DP system, a trade-off should be made between accuracy and speed: the model accuracy should be based on selected thresholds; the computational speed should be such that the model is able to provide predictions well within the real-time simulated duration. In case different scenarios need to be evaluated, parallel computations will be used.

Conclusion

Extending a DP system with a diagnosis system and an operator support system can be based on a system that operates in three different modes: normal operation, alerted operation and emergency situation mode. By introducing these operational modes in the system, the workload of the DP operator can be shifted towards an optimal workload, because he can perform other tasks during normal operation and he is supported in emergency situations.

Optimizing the workload of the DP operator will improve the safety and reliability of DP operations, because the probability of operator errors will decrease due to improved operator alertness. An operational advantage is further that the DP operator is allowed to perform other tasks during normal DP operations which might reduce the amount of marine crew.

Working with the three modes of operation required that the DP system has a self-diagnostic function, which can detect a fault in the DP system. Once a fault is detected the operator is called and the fault is analyzed to provide the operator with advice on how to solve the problem. To further support the operator, a number of scenarios can be simulated online to determine which solution strategy gives the best chances of preventing an incident.

For fault detection purposes a combination of consistency verification by (fuzzy) rule based systems and verification by simulation models shows the most promising technique. For operator support a simulation model could be used that predicts the response of the DP system on a number of possible actions to solve a problem in the system.

References

[Adamson & Abrahamsen, 2006]

A. Adamson & B. Abrahamsen: *WSOG – History and Future. A Summary of the Development and Worldwide Use of Well-Specific Operating Guidelines*. MTS Dynamic Positioning Conference 2006.

[Chen & Moan, 2003]

H. Chen & T. Moan: *Probabilistic Modelling and Evaluation of Collisions Between Shuttle Tanker and FPSO in Tandem Offloading*. October 2003.

[Endsley, 1996]

M.R. Endsley: *Automation and Situation Awareness*. In R. Parasuraman & M. Mouloua: *Automation and Human Performance – Theory and Applications* (pp. 163-181).

[Grimmelius et al, 1999]

H.T. Grimmelius, P.P. Meiler, H.L.M.M. Maas, B. Bonnier, J.S. Grevink, R.F. van Kuilenburg: *Three State of the art Methods for Condition Monitoring*. IEEE Transaction on Industrial Electronics, Volume 46, no. 2, 1999.

[Grimmelius, 2005]

H.T. Grimmelius: *Condition monitoring for marine refrigeration plants based on process models*. ISBN 90-407-2562-4; Delft University Press, 2005.

[Grootjen & Neerincx, 2005]

M. Grootjen & M.A. Neerincx: *Operator load management during task execution in process control*. Human Factors Impact on Ship Design, Genoe 2005.

[IMCA, 2006]

The International Marine Contractors Association: *Analysis of Station Keeping Incident Data 1994-2003*. IMCA M-181, January 2006.

[Parasuraman, 1993]

R. Parasuraman, R. Molloy & I.L. Singh: *Performance Consequences of Automation-Induced 'Complacency'*. The International Journal of Aviation Psychology, 3(1), 1-23, 1993.

[Shatto, 1997]

H. Shatto: *Reliabiliy and Risk Analysis*. MTS Dynamic Positioning Conference 1997.

Corresponding author:

Arjen Tjallema
Bluewater Energy Services B.V.
Marsstraat 33
2132 HR Hoofddorp
P.O. box 3102
2130 KC Hoofddorp
The Netherlands

Tel. +31 (0) 23 567 8587
Fax. +31 (0) 23 554 2150
Email: Arjen.tjallema@bluewater.com

Paper intended for MTS DP conference
Houston, USA, 2007

Keywords:

Dynamic Positioning, operator, workload, DP incidents, unattended operation, operator support, health-monitoring, diagnostics