Demonstrating Multi-layered MAS in Control of Offshore Oil and Gas Production

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Abstract. From a control perspective, offshore oil and gas production is very challenging due to the many and potentially conflicting production objectives that arise from the intrinsic complexity of the oil and gas domain. In this paper, we demonstrate how a multi-layered multi-agent system can be used in a satisficing decision-making process for allocation of production resources.

Keywords: Multi-agent systems, Emergence, Satisficing, Multi-objective, Production Systems.

1 Introduction

The background for our research is oil and gas production in the Danish sector of the North Sea, as described in our work [1]. The DONG Energy E&P operated production platform Siri is used as demonstration case. Production software systems have to be revised frequently, as many oil and gas fields are maturing rapidly. Simply applying the same relatively fixed production software systems as of today would result in suboptimal production. The application of a relatively fixed production software system is further challenged by the fact that the growing global request for oil and gas advances technological achievements which allow fields to evolve beyond their original abandonment point.

2 Main Purpose

The main purpose of this demo paper is to demonstrate that the multi-layered multi-agent system proposed in our work [1] dynamically can adapt to new operational conditions. This dynamic control is possible as the infrastructure of the multi-layered multi-agent system takes responsibility for coordinating potential interactions among control agents dynamically. Production objectives and system constraints are represented by agents grouped in negotiation contexts at three decision layers. Each

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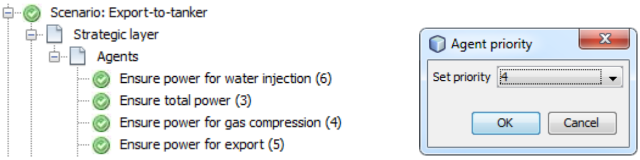
negotiation context holds a mediator agent, which handles the negotiating process in the search for satisficing solutions to the multi-objective production problem. Resource-allocation conflicts may emerge, because agents by default are considered equally important. However, in any non-trivial control system the importance of individual agents may change depending on the actual operational state. This state-dependent change in agents' importance is handled by supporting dynamic prioritization of individual agents. Important agents are given higher priority than less important agents. By default the priority of all agents is set to 5. In the current implementation, we have chosen to use a priority range from 1-10 (1 = highest and 10 = lowest). Fig. 1 depicts to the left examples of agents at the strategic layer, with their priorities in round brackets. To the right is shown the GUI used to change agent priorities at runtime.



- Scenario: Export-to-tanker
  - Strategic layer
    - Agents
      - Ensure power for water injection (6)
      - Ensure total power (3)
      - Ensure power for gas compression (4)
      - Ensure power for export (5)

Agent priority

Set priority 4

Fig. 1. Agents' priority

3 Experiments

In this demo-paper we use the same export-to-tanker scenario at the Siri platform as described in our work [1], but here with different production configurations using synthetic data. Production configuration refers to availability of production systems and priority of production objectives. The export-to-tanker scenario involves all three decision layers, and is based on oil export to a shuttle tanker from an intermediate storage tank on the seabed. Due to limited electrical power resources under normal operational production conditions at the Siri platform, one of the major power consumers has to be stopped during the export-to-tanker scenario, i.e. either a gas compressor or a water injection pump. The gas compressors are used to handle produced gas either for use as fuel, lift gas (lift gas is used to reduce density of the well fluid to allow the well inflow pressure to overcome the hydrostatic pressure of the fluid column) or re-injection of surplus gas to minimize CO_2 emissions. The gas compressor system consists of three compressors. Water injection is used as pressure support in the reservoirs in order to maintain an economically-feasible production. The water injection system consists of three pumps. Fig. 2 shows the negotiation contexts (solid rectangles) that are directly involved in the experiment.

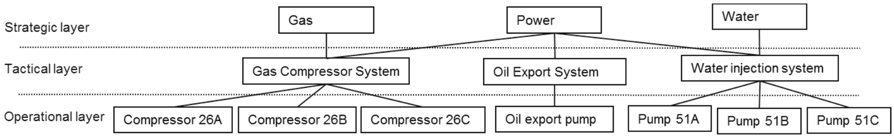


Fig. 2. Experiment negotiation context diagram

The experiment can be split into five phases marked by numbers in Fig. 3 and Fig. 4. Fig. 3 shows the agents' responses to the actual solution, found by the mediator agents, in the form of a fitness value 0-100 [%], where 100% indicates a complete satisficed agent. Fig. 4 shows the water injection system flows [m^3/h].

Experimental preconditions: A) The three water injection pumps are in service with a total capacity of 900 [m^3/h] HP (High Pressure) water to the Siri platform and satellites installations. B) Power to gas compression has lowest priority. C) Export to tanker has not commenced.

1. The export-to-tanker scenario is triggered by the *Oil export system* at the tactical layer, and by requesting power from the *Power* negotiation context. The *Power* mediator agent starts a negotiation process to find a new power plan. The *Power* negotiation context contains the following agents: *Ensure power for water injection*, *Ensure total power*, *Ensure power for gas compression*, *Maximize total power allocated*, and *Ensure power for export*. The new power plan makes, as seen in Fig. 3, the *Ensure power for gas compression* agent respond with a fitness of 83%.
2. The *Ensure power for water injection* agent is given the lowest priority. The *Ensure power for gas compression* is now satisfied, whereas the *Ensure power for water injection* has a fitness of 33%. As seen in Fig. 4, one water injection pump is stopped, i.e. a total of 600 [m^3/h] HP water to the Siri platform and the satellites.
3. The stopped water injection pump is taken out of service for maintenance. The *Ensure power for water injection* has now a fitness of 100%, whereas the *Mixed water request* agent has a fitness of 50%. As seen in Fig. 4, two water injection pumps are still running.
4. The export-to-tanker scenario is completed and the *Maximize total power allocated* agent indicates that a surplus of power is available due to the pump that is out of service for maintenance reasons.
5. The water injection pump that is out of service for maintenance reasons is put back online. As seen in Fig. 4, all water injection pumps are back in operation.

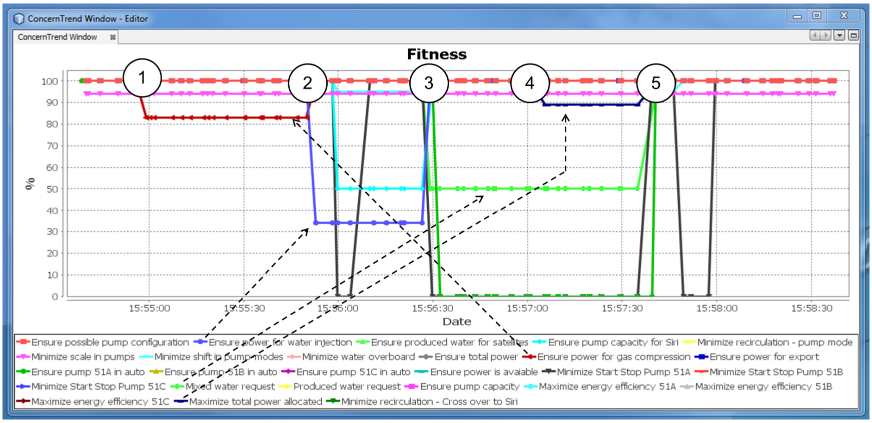


Fig. 3. Agents´ fitnesses

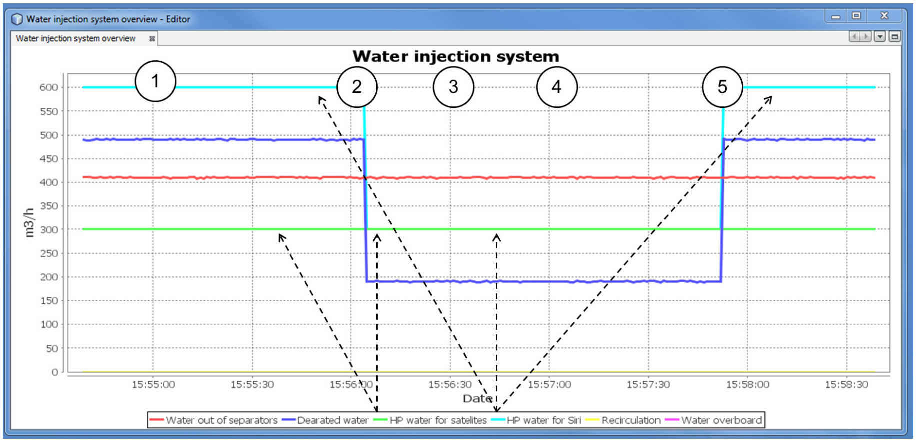


Fig. 4. Water injection system flow [m^3/h]

The trend curves *Water out of separators* and *Dearated water* in Fig. 4 are water supply to the water injection pumps, whereas *Recirculation* is used when ensuring a minimum flow in the pumps and *Water overboard* is used if there is a surplus of *Water out of separators*.

4 Conclusion

We have demonstrated by different production configurations in the same production scenario that a satisficing decision-making process implemented as a multi-layered multi-agent system can handle the changes in full automatic mode. Hence, we believe that the proposed approach [1] possesses the capability to face the continuously changing operational conditions of oil and gas fields. The proposed approach provides a new level of flexibility that meets the need for dynamic evolution of oil and gas fields not seen in the manually controlled systems, as is currently the state of the art within the oil-and-gas-production domain.

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Reference

1. Mikkelsen, L.L., Demazeau, Y., Jørgensen, B.N.: Multi-layered satisficing decision making in oil and gas production platforms. In: Demazeau, Y., Ishida, T., Corchado, J.M., Bajo, J. (eds.) PAAMS 2013. LNCS, vol. 7879, pp. 170–181. Springer, Heidelberg (2013)