Achieving Autonomous Operations

An end-user focused approach and maturity model by WIB/NAMUR

#autonomous plants #ai #process industries

The level of autonomous operation of a plant can be described by the so called "Autonomous Operation Maturity Levels". These levels range from 0 (all manual) to 5 (full autonomous operation). This contribution gives guidelines to assess the maturity level of existing plants and identify necessary tools, hardware and programs to achieve the next level of autonomy. This is summarized in three matrices for the following categories: Asset Management, Process Management, and Production Management.

Der Grad des autonomen Betriebs einer Anlage kann durch die so genannten „Autonomous Operation Maturity Levels" beschrieben werden. Diese Stufen reichen von 0 (vollständig manueller Betrieb) bis 5 (vollständig autonomer Betrieb). Dieser Beitrag beschreibt Leitlinien zur Bewertung des Reifegrads bestehender Anlagen und zur Ermittlung der erforderlichen Werkzeuge, Hardware und Programme, um die nächste Stufe der Autonomie zu erreichen. Dies wird in drei Matrizen für die folgenden Kategorien zusammengefasst: Anlagenmanagement, Prozessmanagement und Produktionsmanagement.

Ruud Litjens, Cargill;
Hans-Jürgen Henkel, Nobian (retired);
Jacco Opmeer, Shell

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1. Introduction

The future will confront process industries with major challenges. Among these are increasing productivity and demand for more sustainability in all regions, greater flexibility in production and business processes, demographic changes, and the availability of experts in growth markets. Optimizing operational models by implementing automation and digital technologies is one of the most fundamental possibilities to cope with these challenges, provided that the human element is properly considered as well.

Remote and autonomous operation (AO) concepts for plants provide a way to face these challenges. To achieve the economic goals associated with remote and autonomous operation, technological, human, social, and legal aspects need to be considered. Compromises on safety aspects are neither acceptable nor necessary since the respective technologies also offer potential to enhance process stability and surveillance.

NAMUR has published Recommendation NE 161 "Remote Operation Basics" [1] in 2016, suggesting three autonomy levels. In 2020, ARC [2] published an Autonomous Operations Maturity Model. The level of autonomous operation of a plant is described by the so called "Autonomous Operation Maturity Levels". This model suggests using level 0 as non-autonomous plant and levels 1 to 5 defining higher levels of automation (levels 1 and 2) and autonomy (levels 3 to 5). ARC describes the levels in a general form but gives no specific information for the implementation of the levels.

WIB's "Autonomous Operations Working Group" and NAMUR's WG 4.20 "Remote and Autonomous Operation"

Figure 1: Categories for Autonomous Operation.

went to the details for three categories needed for Autonomous Operation:

- Asset Management
- Process Management
- Production Management.

For each Category, an "Autonomous Operation Maturity Matrix" (AOM Matrix) has been created. This paper describes the concept of these matrixes.

2. Autonomous Operation Maturity Levels

This paper is based on maturity definitions (5 levels) as proposed by ARC [1], but we have redefined, refined and extended these definitions. A clear state definition for each maturity level and a common understanding is key. The levels 1 & 2 are deemed foundational and are not considered. To establish the foundation for our AOM Matrix, levels 3, 4 and 5 have been interpreted as follows:

- **Level 3 "Advanced Regulatory / Predictive":** Selected process units are semi-autonomous, human interventions are required when outside defined operating conditions.
- **Level 4 "Select Autonomy / Prescriptive":** Selected process units are autonomous between planned shutdowns that allow for replacements, upgrades and expansions. Human interactions are limited to non- or semi-autonomous process units. Unexpected shutdowns due to equipment breakdown are exceptional and minimized.
- **Level 5 "Autonomous":** All process units are autonomous between planned shutdowns that allow for replacements, upgrades, and expansions. Human interactions are maintenance-centered during planned shutdowns. There are no unexpected plant stops due to equipment breakdown. Where Process, Production and Asset Management is still essential within the context of autonomous plant operation at this level, they are largely merged and have become part of an integrated organization.

3. Categories to be covered for Autonomous Operation

For an Autonomous Operation, three Categories have to be covered:

- **Asset Management:** Each level of AO has requirements for the plant assets to enable this Operation. Assets must be designed and managed to fulfill these requirements.
- **Process Management:** Similarly, AO requires an appropriate process management for each AOM level.
- **Production Management:** Also, the production management must provide all relevant services and information needed for the levels.

Supply chain-related topics within the scope of the matrix are assigned to the Production Management domain. Consequently, the matrix does not cover Supply Chain Management functions at the business level (typically managed in ERP systems). Instead, it focuses on translating business needs (such as production requirements, resource tracking, planning, and scheduling) into appropriate functions at the plant level, orchestrated by Production Management. Figure 1 illustrates this graphically.

4. The Autonomous Operations Maturity Matrices

For each of the categories mentioned in section 3, an AOM Matrix has been created. This section describes the rows and the columns of these matrices.

4.1 Vertical dimension of the AOM Matrices

The vertical dimension displays all swim lanes with their respective states and transitions, as outlined in Figure 2, which provides an overview of the table of contents for the three categories Asset Management, Process Management and Production Management. E.g., Asset Management includes Design of equipment, Measurability of asset properties, Condition monitoring, Maintenance Strategy and Execution and IT/OT foundations. Each of these topics consists of 3 to 5 subtopics as shown in the last column of Figure 2.

Autonomous Operations Working Group

WIB Process Automation Users' Association

NAMUR

Framework document

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Link to Level Definitions
Link to Abbreviations

Production management		
	Event management	Events from HSE Events from Maintenance Events from necessary operator tasks Conflict management
	Production orchestration (MES/MOM Functionality)	Detailed scheduling Dispatching Track & trace Performance analysis
	Integration of business systems into plant production execution (personnel Process interface/clusters interaction)	Integration of autonomous plants in site cluster Production to Business integration (from CRM(ERP) to work orders in the MES) Production to supplier integration (From ERP (Bill of Material, Recipies) to MES work orders)
Process Management		
	Process execution	Alarm Management Control loop performance Process control State based control Asset integration HMI
	Process modelling	Process analytics Embedded Analytics Process performance & KPI's Process Modelling & Digital Twin
	Operator Training Simulator (OTS)	Operator Training System (OTS)
Asset management		
	Design of equipment	Design requirements Criticality ranking (CR) Asset OEE tracking Vendor integrated improvement process Asset Standardization
	Measureability	Improve measureability Improve robustness of sensors Integrated and performing data transfer from sensor to data storage
	Asset condition Monitoring by embedded analytics	Defined digital operating window of assets Embedded Analytics Soft sensors Advance pattern recogonition Asset interface to process
	Maintenance strategy	Asset strategy Maintenance requirements of assets Maintenance job execution preparation
	Maintenance execution	Digital available asset information for maintenance Digitization of maintenance job execution Replacement of human activities by robots
	IT/IIOT/OT Foundations	Asset identification in field area Asset master data in CMMS/ERP/Engineering systems available Asset operation data in structured form in datalake (UNS) Data & Systems

Figure 2: Impression of the table of contents.

4.2 Horizontal dimension of the AOM Matrices

Horizontally, for each dimension described in 4.1 the transitions from one level of AO to the next, which primarily involve implementing functionalities to reduce human interaction, are detailed and categorized by subject. The matrix is organized using "swim-lanes" to indicate the required process flows. Typical criteria and solutions are described. So, the AOM Matrix assists users in identifying their current level of Autonomous Operations (AO) and guides them through the necessary transitions to advance to the next AO maturity level.

The columns in Figure 3 are:

- Transition from level 2 to level 3 (in grey)
- Features required for level 3
- Transition from level 3 to level 4 (in grey)
- Features required for level 4

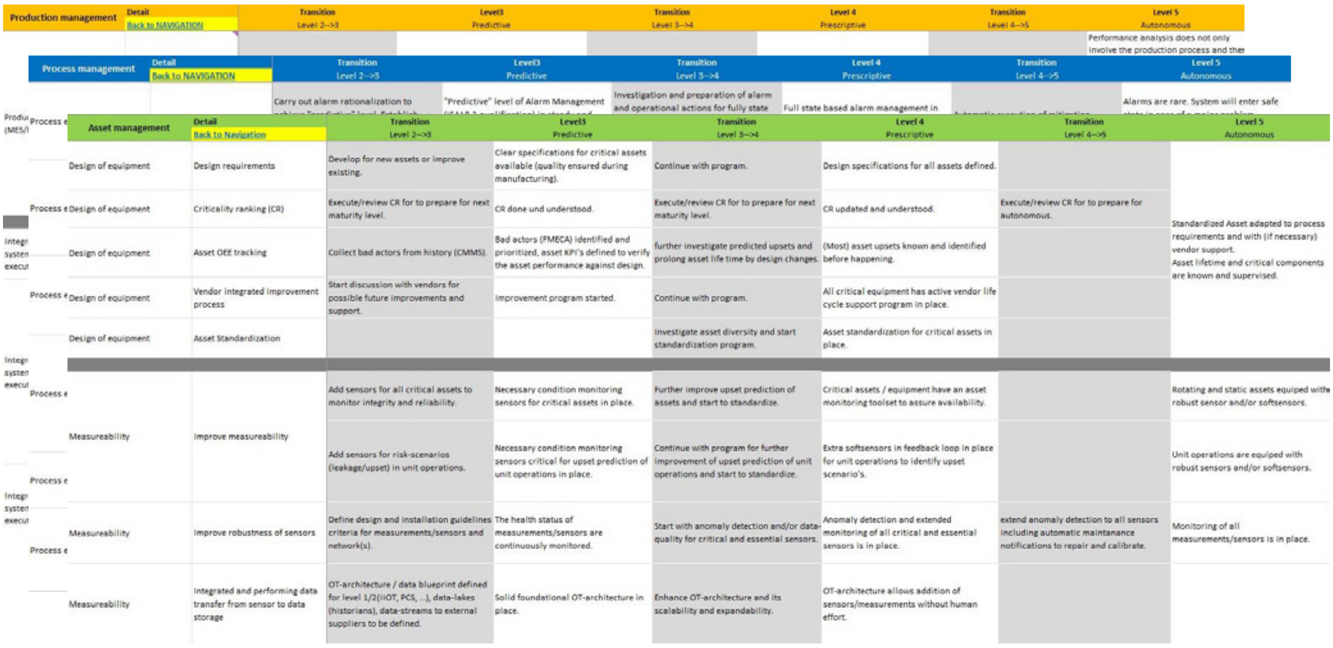

Figure 3: Impression of the matrices covering 3 domains.

- Transition from level 4 to level 5 (in grey)
- Features required for level 5

The AOM Matrix provides a generic description of what should be done to pursue the next level of autonomous operation. The reason this is kept generic is that many companies have different approaches and workflows. However, the development of the document showed that work areas, as well as states and transitions, are very similar.

4.3 Example

This practical example is drawn from one of the many rows in the matrix, specifically highlighting one of the aspects, in this case process control related. Imagine a chemical production company, that has been operating for years using traditional process control. Operators monitor the processes and intervene when necessary. This is the starting point - Level 2.

Transition to Level 3 – Predictive Control

The company decides to improve its process control. They implement advanced control strategies such as feedforward control and model-based control (MPC). This allows them not only to react to deviations but also to predict when a process might go off track.

Result: The plant reaches Level 3. Processes are now more stable, especially during steady-state operation and load changes.

Transition to Level 4 – State-Based Automation

After this improvement, the company notices that startup and shutdown procedures still require a lot of manual intervention. They integrate their process control with **state-based automation**. This enables the system to recognize its current state (e.g., startup, normal operation, shutdown) and respond accordingly if anything changes or certain events occur.

Result: The plant reaches Level 4. Most process steps now run autonomously, with minimal human involvement.

Transition to Level 5 – Full Autonomy

As a final step, the company further extends fallback strategies in case key measurement instruments fail. Think of automatic switching to backup sensors or adjusted control modes. At the same time the state-based automation can take decisions to deal with this situation and keep the plant running till a planned shutdown. Additionally, control loops become adaptive, automatically adjusting to changing conditions.

Result: The plant now operates largely autonomously, even in unexpected situations. This is Level 5 – robust, self-correcting, and future-ready.

5. Conclusion and Outlook

The AOM Matrix' states and its transitions are indicative for the steps and the direction companies need to follow to achieve their aspired level of autonomy. As we learn through time, the matrix and more particular, its transitions might have to be tweaked to represent better solutions. We count on the community of both WIB and NAMUR to provide feedback, which will enrich and enhance the matrix for our further use.

This article summarizes the joint WIB and NAMUR efforts to help end-users taking steps towards achieving a more autonomous operation and intends to inform a broader audience of our activities. With this article we like to trigger enthusiasm from you, to use the matrix, helping you to achieve higher levels of autonomy in your assets.

If it piques your interest, you want to know more, or contribute to further development, you can express your interest via: consultant@wib.nl.

References

[1] NAMUR. (2016). NAMUR NE 161 "Remote Operation Basics", Standard.

[2] ARC Advisory Group. (2020). ARC Level definitions. Retrieved from: https://www.arcweb.com/blog/what-autonomous-operations.

Ruud Litjens is Regional Process Control and Automation Engineer and is driving innovation that brings Cargill's facilities closer to autonomous operations. He is chairman of the WIB Industrial Automation Control Systems Working Group, previously leading the Autonomous Operations Taskforce, guiding the development of the foundational material featured in this article.

Ruud Litjens
Cargill
WIB Autonomous Operations Working Group

Hans-Jürgen Henkel is Subject Matter Expert on Process Digitalization and was working on Nobian's Digitalization Strategies. He has been co-leading the IGR (Interessengemeinschaft Regelwerke Technik e.V., Frankfurt) for a number of years and has more than 35 years of experience in the Process Industry in Engineering, Operations and Maintenance.

Hans-Jürgen Henkel (retired)
Nobian
WIB Autonomous Operations Working Group
NAMUR AK 4.20 „Remote and Autonomous Operation"

Jacco Opmeer works as Principal Automation Engineer at Shell Global Solutions B.V. He is Subject Matter Expert on Process Automation Systems and is working on Shell's Global Automation Strategies. Jacco has been co-leading the Open Process Automation Forum for a number of years, with a focus on creating a healthy business environment through the adoption of a fit for purpose O-PAS™ standard. In addition, Jacco is Executive Board member in the International Process Automation Users Association WIB, a sister organization to the NAMUR and has more than 35 years of experience in the Process Industry in Engineering, Operations and Maintenance.

Jacco Opmeer
Shell
NAMUR AK4.20 "Remote and Autonomous Operation"