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Energetic Equipment Maintenance Logistics: Towards a Lean Approach

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Abstract: Energy production and distribution requires an optimal functioning of all its equipment. That cannot be insured without an efficient maintenance policy maintaining the availability of material and non-material resources which are employed for the production or the distribution of electrical energy. The current energy context imposes several constraints among other those of costs optimization and environment preservation. The lean that is still marginalized in this context and limited to the manufacturing sector remains a promising concept for an efficient maintenance of energy equipment struggling against wastes, contributing to performance improvement and respecting the environmental balance. In this study, we try to describe a green maintenance strategy for energy equipment in the framework of the "lean" philosophy by proposing a practical model for a generic method conception to implement lean tools, integrating the spirit of Kaizen and participatory management in maintenance management, so as to converge towards maintenance logistics inspired by the lean culture to optimize its resources.

Key words: Equipements energetiques, logistique maintenance, philosophie lean, LEAN DIFEE, 5S Kaizen, participating management

INTRODUCTION

The industrial environment develops increasingly more complex constraints to energy production or distribution systems, what makes the performance notion depend on the energy equipment availability. A permanently available energy system cannot be guaranteed without a maintenance logistics vision optimizing all resources. This strategy cannot be fruitful without a concrete approach stating practical tools promoting wastes elimination in energy equipment maintenance to work around equipment availability problems successfully. It is the lean thinking culture that is experienced in manufacturing to build lean production systems and that we judge an efficient, optimal and useful culture to make of maintenance not only executable operations with less costs but a whole optimized logistics system.

MATERIALS AND METHODS

Electrical grids: The electrical grid is a totality of infrastructures and equipment having in charge the transportation and the distribution of the electrical energy from of production centers until final consumers as well as the monitoring of the balance between the energy demand and its production continuously (Fig. 1). The electrical system insures another function: that of transformation by delivering to users consumption good "electricity", characterized by a power, a voltage depending on the customer need as well as by a service

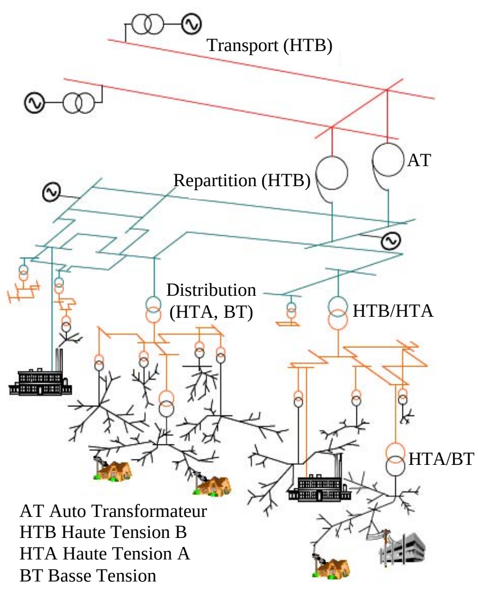

Fig. 1: Global structure of an electrical grid (Carrive, 1991)

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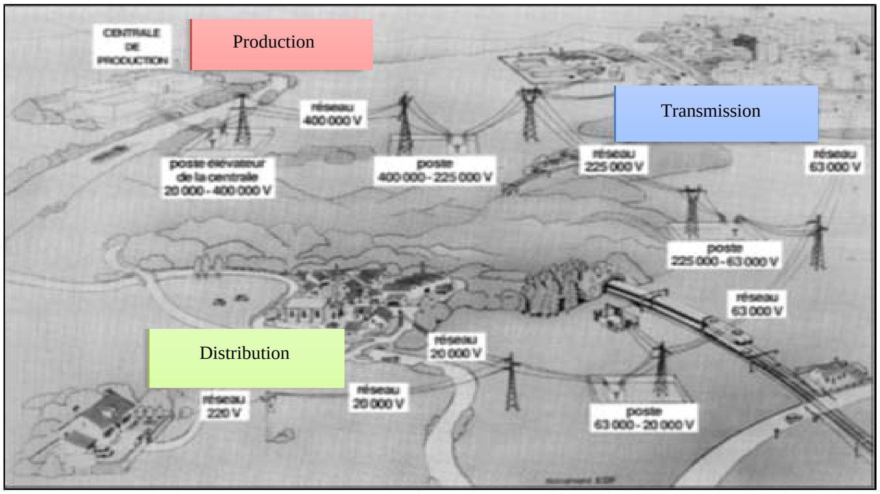

Fig. 2: Elecricity feeding grid (RADEEF)

quality reflecting the capacity to respect and maintain over time the characteristics of both first parameters (Carrive, 1991).

In this grid we can distinguish the following decomposition. The transmission grid: a high voltage grid type B that forwards electricity from production centers to feeding points (transformer substations) of the distribution grid. The distribution grid: insures the forwarding of energy from a transformer substation to consumers. The distribution of the electrical power has to respect norms of goods and persons security as well as of voltage quality and availability of energy (Megdiche, 2004). The private grid: implanted inside an industrial structure or organism necessitating a high level power for its equipment functioning.

Among most important equipment of an electrical grid: production units, power lines, underground cables, transformer substations including transformers, protection cells, electrical distribution boards, etc. (Fig. 2).

RESULTS AND DISCUSSION

Energetic equipment maintenance; towards lean logistics

From maintenance to maintenance logistics: Logistics refers to an availability centered aspect to be related with "the 7 Rs": "the Right goods, the Right amount, the Right condition, the Right place, the Right time, the Right customer and the Right costs" (Plowman, 1964). For Chankov, Becker and Windt this characterizes logistics in a passive manner and thus add another aspect to the logistics definition: synchronization that is necessary to make of it "an active perspective" (Chankov *et al*., 2014). In fact in this context many other concepts have been discussed such as supply chain collaboration which concerns dependent companies collaboration for supply chain operations planning and execution instead of doing it on each company's own (Simatupang and Sridharan, 2002), hence, maintenance should also be observed from an integrating collaborative angle to make of it more than independent executable operations but a whole logistics system called: maintenance logistics.

Maintenance logistics is all resources, functions and management means which remain indispensable and requisite for maintenance execution.

Maintenance logistics manages material and non-material resources to allow a smooth running of maintenance activities. Maintenance logistics dealt with from a systemic approach vision could be a supporting system compound of three subsystems interacting with each other by means of ascendant and descendent flows (Hammadi and Herrou, 2016) (Fig. 3 and 4):

- Maintenance physical subsystem
- Maintenance information and communication subsystem
- Maintenance strategic management subsystem

Maintenance logistics can be considered itself included in other systems such as the production or distribution system and more generally the supply chain logistics as shown by Fig. 5.

Lean in maintenance logistics: The context of the lean allows enterprises to remain competitive in new market shares and constraints determination (Abdulmalek and Rajgopal, 2007). This principle that has become largely

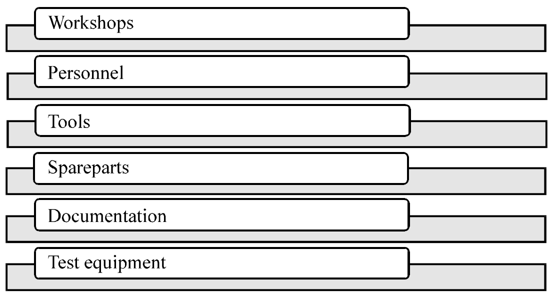

Fig. 3: Examples of maintenance logistics resources

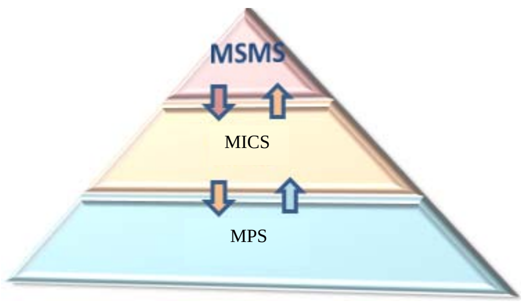

Fig. 4: Maintenance logistics system

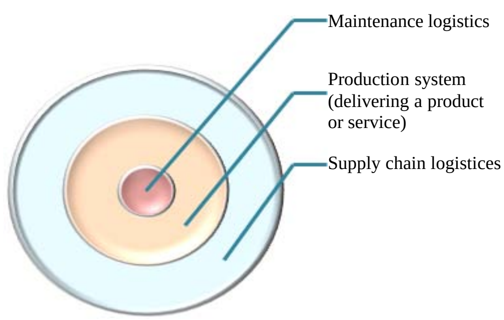

Fig. 5: A production system's maintenance logistics position

largely used in manufacturing stays poorly explored in maintenance. It is therefore, essential to understand the meaning of lean maintenance that has been introduced in the 20th century (Mostafa *et al*., 2015) and which could be defined as "a proactive maintenance operation using planned and programmed maintenance activities through Total Productive Maintenance practices (TPM) using maintenance strategies that are derived from the application of the decision logic of the reliability based maintenance by an autonomous team" (Smith, 2004).

Lean maintenance logistics is therefore, the totality of maintenance human and material resources in addition to its management means in the framework of the lean philosophy. It is the wise alternatives adaptation of the lean culture to manage maintenance resources, interactions and projects to make maintenance processes lean "banishing waste and creating the wealth" as lean was described by Womack and Jones (2003).

Towards an implementation method for energetic equipment: Considering the example of the most important device having the most costly consequences in electrical energy distribution: the transformer. This equipment has known a prominent conception evolution passing by a park of protection equipment connected to the transformer and reachingthetransformer with functions of integrated protection-disconnection in the objective to suppress all risk external manifestation (opening of vat, propagation of an arc to the exterior of the machine, fire) (Grima and Faitermeier, 2001). In fact "transformer's disasters are behind 50% of exploitation losses in energy production industry, 10% in chemical industry, 7% in paper mills and 6% in commercial enterprises". A sudden breakdown in a transformer disturbs the totality of the operating system provoking, thus, energy delivery problems and arising maintenance costs as well as the potential of related risks among others environmental risks (Betie, 2012).

A transformer has to be maintained in operational conditions continuously, so as to avoid: abrupt transformer breakdowns allowing possible fires and pollution risks to take place and also for the rest of equipment, a policy of efficient maintenance logistics remains essential and has to be implemented, so as to minimize electricity interruption causing major losses at all scales. In this vision, a culture of performance optimization and waste elimination will be the guiding framework for maintenance logistics having recourse to the "lean" philosophy to manage this logistics and control its activities.

So, as to implement the "lean" inenergy equipment maintenance logistics, it is important to focus on its tools among others the 5S that are fundamental for the implementation of the lean strategies (Rojasra and Qureshi, 2013). It is a method that allows a daily improvement of an organization production and quality systems following a succession of steps aiming at achieving efficiency, cleanness and standardization in work procedures (Munozand Bueno, 2012). Each S of the 5S has a general meaning as described by Fig. 3. The last S refers to the standardization and adoption of the other steps as a culture of the organism that will be practiced systematically (Fig. 6 and 7).

Following the same step in the framework of the corrective or preventive maintenance during of an intervention on a Transformer Substation (TS), we propose the tool 5S-TS which is generic and may be adjusted to fit another energetic equipment kind usefully (Table 1).

Table 1: 5S-TS tool

Factors	Description
Seiri	Keep only uesful materials and tools inside the TS
	Avoid putting consumables (oil, degreasingessence, ...,) on transformers or in close proximity to cables or other electric devices of the TS
Seiton	Limit useless moves or displacement inside or outside the TS in search of maintenance/adjustments/control and measurement kits
	Never let accessible the TS to the other persons during intervention
	To order the needed kit so as to find tools easily as well as spare parts by verfying a check-list before the intervention Seiso clean TS equipment that necessitates it according to quality/security norms of electrical equipment and in compliance with the norms and instructions already definedy by the energy distributor/equipment responsible institution or producer
	Control the cleanness of spaces/organs of aeration/escape of positions of transformations systemmaticaily
	Dust temperature and prwssure display devices and to insure their adjustment and system atic calibration
Seiketsu	To keep the traceability of all problems maintenance and contorl operation to construct a detalled database reflecting the availability of the TS
Shitsuke	Standardize these steps for other energetic equipment and exploit the feedback of maintenance interaction between opeperators, supervisors, engineers and the equipment

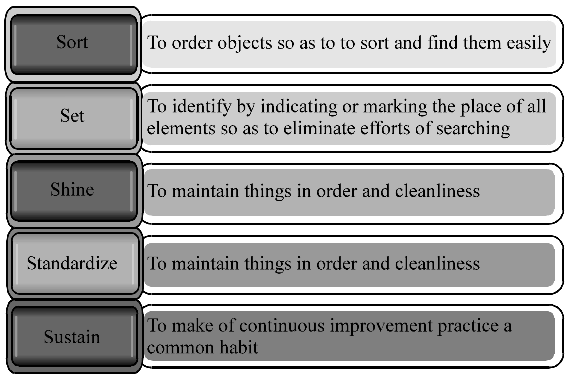

Fig. 6: The 5S tool (Ramdass, 2015; Omogbai and Salonitis, 2017)

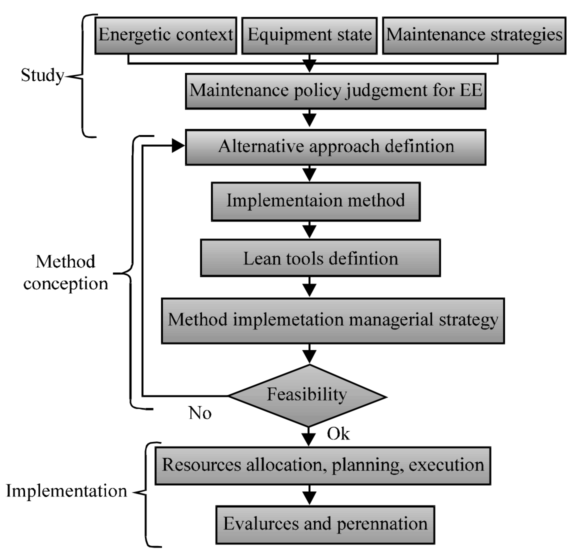

Fig. 7: Algorithm for designing the method

So, as to converge to lean maintenance logistics for energetic equipment, it is necessary to valorize the return on experience of the human factor in the continuous improvement process that remains one of the most important pillars of the lean philosophy in all processes or services of the organism. This daily improvement culture "kaizen" requires the engagement of all operators or managers of the lean manufacturing for waste elimination. Randhawa and Ahuja (2017) To import the lean manufacturing benefits to the lean maintenance logistics of energetic equipment, it is essential to involve all operators. Furthermore, all the organism concern and effective involvement is indispensable to project waste elimination culture on the execution arena. This concept cannot be concretized without a method calling to participatory management to put into practice the continuous improvement and adapt it to fit the specific context of maintenance logistics and energetic challenges. The general algorithm of the method conception is described in Fig. 7.

CONCLUSION

Energy efficiency challenges are various as well as maintenance strategies. However, the most optimal is which insures energy equipment availability avoiding all extra expenditure or non-necessary investment. On this guideline maintenance logistics has to define its alternatives exporting and extracting the benefits of the lean culture based on its tools among others: 5S.

In this vision, we propose a waste elimination approach in energy equipment maintenance based on the 5S this tool as well as others can be standardized and better exploited through an innovative method, integrating participatory management in the continuous improvement process to construct a culture of maintenance logistics managing the totality of its resources with the lean spirit that is at the same time green in fact, waste reduction techniques are considered the linking bridge associating the green to the lean culture (Fercoq *et al*., 2016).

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