Standpoint of the EDF operator of nuclear power plants

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1 - EDF General Policy in terms of and remote systems for the nuclear generation capacity

Safety and competitiveness are the sine qua non conditions to the durability of the nuclear industry in France, as in the other countries involved in electronuclear programs.
Improving safety, increasing availability and mastering the costs are inseparable and interactive aims, and the cooperating actions are to be managed simultaneously.

Another aim is the undivided attention given to radiation protection. The average annual collective dose per unit has slightly decreased since 1993 despite an increase in the circuit activity and the volume of the works. This result is not thoroughly satisfactory if compared to the performances carried out abroad on similar reactors.

EDF has therefore decided to revise the establishments of contracts with the contractor companies on the following bases :

- a lasting partnership bases on common aims, mutual obligations, and shared benefits
- complete and better integrated services, giving the companies a greater responsibility on the means to be implemented to achieve those aims
- pluriannual contracts, enabling the companies an improved insight of the future load, and thus giving them the opportunity to invest (in personnel training, in tools or in innovation processes, etc.),
- permanent research in the field of the best technologies available in France and abroad, through supplier diversification and international experience feedback.

2 - Maintenance: main intervention field of robotized or remote systems

Robotics is an improvement factor for **maintenance** together with the optimization of programs and organizations and the improvement of performances of the repair **processes** implemented.

Robots are used to implement, in a generally hostile environment, maintenance processes for which the maintenance contractors and EDF have at their disposal specialized skill, mainly :

- welding and related techniques (machining, cutting, ...),
- non-destructive examinations (visual, ultrasonic, eddy currents, dye penetrant testing .),
- handling measurement instrumentation (metrology, vibration, temperature, exposure/contamination ...),
- setting up specialized tools (component assembly or disassembly ...),
- constraint works (setting up shields, air-locks, decontamination ...)

In the field of maintenance, robots and remote systems concern :

- the reduction of personnel exposure to irradiation and the anticipation of more severe regulations in this field,
- productivity increase aiming at an improved availability and a decrease in contractor costs,
- a higher tool changeability to reduce the direct development costs, the costs induced by the storage and the maintenance of contaminated components, as well as an improved integration of work sites requiring several successive processes during outage,
- a higher process reproducibility,
- an improved interventions data memorization capacity,
- adaptable solutions for exceptional or accidental situations in which man cannot act.

This list illustrates the many sides to developing robotized systems. Considering the nuclear plant specificities (geometry, admittance, environment), the development costs and the numerous targets aimed at, the purely technical approach is no longer adequate: the goal is to establish a system in which the maintenance processes, the economy in the broad sense of the term, and the participants are carefully assessed and measured out according to the aims. Apart from this "system" approach, developing robotized systems entails very severe technical and economical risks.

Robots and remote systems are globally considered as possible intervention means competitively to other means, in the following situations :

- Planned maintenance

The nuclear generation capacity maintenance is essentially preventive. The preventive maintenance operations concern components in a non-failure state and cover various techniques: inspections, examinations (eddy currents, ultrasonic, X rays,...), repairs (excavation cavity, welding,...). They are defined and planned according to preventive maintenance programs. Most are carried out during refueling outage occurring every twelve or eighteen months.

- Exceptional maintenance

Exceptional maintenance corresponds to repairing, refurbishing or replacing parts subject to unexpected damages. As an example, the crack in the vessel head adapters required the implementation of a three-fold problem determination strategy: adapter control to detect possible cracks, repair and refurbishment of the vessel heads. to this example. robots played an important part in the control.

- Post accidental interventions

The post accidental situations taken into consideration go as far as partial core meltdown with or without radioactive release outside the plant.

A distinction must be made between the needs in identification and preparation of the environment on the one hand, and the actual maintenance or operation interventions on the other hand.

Due to the high number of unknowns which are the main concrete characteristics in this type of scenarios, it has not been estimated realistic to enter into robots or remote systems to achieve maintenance (components repair or replacement ...) or operations (device operations...) strictly speaking.

The development focuses as a matter of priority on robotized or remote control systems for environmental survey (radioactivity, temperature, obstacles, identification of the state of equipment ...) prior to the operation itself. Robots or remote systems may nevertheless have a useful application as a means of assistance to the operator (tool carrier, protection shields ...) or even to carry out first level light interventions (sealing off leaks, picking up objects ...).

These applications are entrusted to GIE INTRA, in charge to developing and maintaining a set of mobile equipment into operation on behalf of three French nuclear operators : EDF, CEA (the French Atomic Energy Commission) and COGEMA.

- Robotized or remote systems maintenance of the future standardized plants

Experience feedback has shown the difficulties in relying on robots or remote systems when the interventions have not been considered in the original design of the plants. Being the industrial architect of its own plants, EDF takes part in designing the future plants so as, subsequently, to facilitate the implementation of robotized or remote systems. The arrangements contemplated mainly concern the high capacity communication networks, easy ways to achieve absolute locating in space, a less constrained spatial environment.

3 - Short historical review

During the design of nuclear power plants, a certain number of arrangements were made to facilitate maintenance operations, in so far as they could be planned. A certain number of accesses, of utilities, of pressure equipment access ports have thus been planned according to the corresponding timely criteria: maintenance type and volume, technology of the maintenance means, degree of equipment contamination, health physics regulations. In addition to the design rule book, there were compulsory in-service inspections criteria for the important to the safety equipment. To this effect, a certain number of tools were designed and supplied from startup: In-service inspection machine, automatic controller of the steam generator tube bundles

("Spiders"). As for a certain number of maintenance operations directly linked to plant operation, tools have been designed almost as early as the beginning to reduce personnel integrated doses or to improve the quality of operations (consideration for the parameters, traceability, productivity): simultaneous stud tensioning machines, fuel handling station.

These two concomitant factors modified the initial data and justified deep changes:

- the progressive discovery of youth defects requiring, on the one hand, interventions on equipment not initially planned in the maintenance programs, and, on the other hand, the intensification of control or maintenance programs on a certain number of equipment,

- the evolution of technologies in the field of maintenance tooling (power actuators, instrumentation and control equipment, sensors ...) which progressively enabled the development of remote machines such as spiders towards robots allowing a greater site integration and an increased supervision of operations.

Competition was therefore stimulating and the technical evolution enabled the realization OT the t projects. The robots thus replaced automatic machines. The [movements of the automatic machines (Spiders, SMOR...) are tdesign indexed according to the steam generator tube plate. They are controlled by on-off sequencers. The multi jointed robots (ARAMIS for FRAMATOME, ROSA for WESTINHOUSE, RITMIC for INTERCONTROLE, FLEXIVERA fort ABB-CE) can reach the entire work area, change tools or process without carrier replacement (See figures 1,2,3).

Technologically, this evolution was only possible because of the contributions from the industrial sectors independent from the nuclear industry: this is probably one of the main lessons for the future. To be more precise, this evolution was due to the contribution of hardware and software progress to instrumentation and control. All the instrumentation control "layers" have undergone profound evolution, from the lower level of servo-control up to the supervisor responsible for quality and data memorization capacity.

4 - Research and Development in Robots and Remote control at EDF

3.1 - Main objectives

EDF intend keeping a Research & Development activity in Robotics and remote control operations for several reasons :

- on the one hand, to have some knowledge and an ability of assessing the technologies available in France and abroad, a standing action of technological survey being carried out on the subject,
- on the other hand, to carry out research and development actions in a certain number of fields considered significant so as to have a technical expert assessment available, and to participate in the removal of certain technical locks; these: actions are either achieved on technological components (or technological bricks), or in selected subject themes.
- and lastly, to stress the interest of the process with laboratory experiments, and the possible improvements.

Part of this process is achieved within a pluriannual Research and Development Project: the START (Projet de Système de Téléintervention Avancé Robotisé Transposable, or "Advanced Remote Robotics system for Intervention project"). Part of this R&D also concerns the use of remote systems and robots for non nuclear EDF applications interventions on energized electric lines, robotized repair of hydraulic turbines bladings, etc.

4.1- Handling systems

The current approach consists in identifying the handling systems available on the market and to assess their capacities. Some adaptations and improvements may then be suggested and carried out. One of the handling systems withheld is the hydraulic industrial robotics arm (SCHILLING TITAN) with a high load capacity of around a hundred kilos as comparable to its own weight. It has been characterized and has been implemented for various demonstration operations in remote control or robot mode.

It proved necessary to have a second and lighter handling system, with a smaller load capacity and yet higher repeatability characteristics to carry out more precise operations (in particular welding). Following a study of the world market supply, the choice fell on a ten-kilo-capacity industrial electric handling system weighing thirty five kilos, with 7 degrees of freedom. This is an interesting characteristic feature from the point of view