PROGRAMS TO IMPROVE PLANT PERFORMANCE

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ABSTRACT

Looking toward the 1990's, we see a period in which our industry will face the challenge of improving the performance of the nuclear plants which are built and operating. The skills and technology are at hand to make good plant performance a reality and we believe the time has come to use them to achieve that end. As reserve margins decline, utilities and their regulators will increasingly seek to tap the unexploited capacity tied up in plants operating below their optimum availability. This paper describes a number of the programs, plant improvements and operations improvements which can yield a significant increase in nuclear plant availability and capacity factor now and into the 1990's.

INTRODUCTION

During the past decade, the nuclear power industry in the United States has undergone substantial changes. These changes were the result of a myriad of significant factors ranging from international economics to domestic regulatory actions. The oil crisis of the mid-1970's resulted in a world-wide move toward energy conservation which had substantial impact on both actual and projected electrical load growth rates. The revised load growth projections caused utilities to re-examine their need for new generation capacity, and resulted in a large number of power plant deferrals and cancellations (both nuclear and fossil). Furthermore, orders for new power plant additions became almost nonexistent. In addition to these economic factors, the nuclear power industry in the U.S. was also adversely impacted by the Three Mile Island (TMI) accident in 1979 which resulted in a substantial amount of regulatory-imposed design changes and backfits. The plant modifications resulting from the TMI accident have taken about eight years to complete.

As a result of these factors, most utilities with nuclear plants under construction were substantially affected financially as they endeavored to service the significant outstanding debt on their uncompleted plants and to find the capital necessary to implement the required regulatory backfits. This tremendous drain on available capital led many utilities to adopt a similar philosophy about how money would be spent on their operating plants. That philosophy might best be summed up as: "We'll only spend money to fix something if it's broken or about to break, or if necessary to implement a regulatory requirement needed to continue plant operation." Discretionary expenditures to improve plant performance, as commonly measured by capacity factor and availability, were beyond the financial capability of most utilities.

However, as the few U.S. plants still under construction near completion, utilities are beginning to place increased emphasis on improved plant performance. The reserve margins in electrical generation capacity that once existed are, in the absence of new plant additions, gradually diminishing. Yesterday's state-of-the-art technology is today's proven application; and the substantial technological advances made in recent years now provide strong economic incentives for upgrading existing equipment. The Institute of Nuclear Power Operations (INPO), set up by U.S. nuclear utilities to establish standards of excellence within the industry following the Three Mile Island accident, has developed criteria for continuing assessment of individual nuclear plant performance. State regulatory bodies, once engrossed in the task of dealing with rapid additions to generating capacity, are now more closely examining the performance of operating plants as an important factor in assessing prudency of utility-requested rate increases. In short, improved plant performance is becoming an increasingly important consideration for most utilities; and the impetus for improved plant performance will continue to grow into the 1990's.

If overall plant performance is to be improved, then a dedicated commitment to achieving better performance through application of a well-defined, structured process will be needed. Such a process must define the appropriate balance between the various goals of a utility and ensure that available resources are allocated in a manner that will optimize achievement of those goals. The process must also be sufficiently flexible to readily account for downstream changes that are likely to be brought about by a rapidly changing environment. The following is a description of a process for achieving better plant performance that GE and a number of U.S. utilities have developed and successfully applied.

PROCESS FORMULATION AND DESCRIPTION

The process begins with the documentation of a clear set of goals and objectives specifically applicable to the individual utility and plant seeking improvement. To generate this statement of goals and objectives, the question of what is meant by optimum overall plant performance must be closely examined. This definition will likely be different from utility to utility, and perhaps even among various plants owned by the same utility. Utility managements are driven by different factors - such as the operating and construction plant mix, plant age, and state regulatory bodies. Thus, differing plant-to-plant definitions need not be of concern and are, in fact, justified. In any event, all such factors must be considered, and an independent parameter list established to define the appropriate set of plant-specific goals and objectives.

These factors can be generally categorized into three major goal-related categories: regulatory improvements, economic generation improvements, and all others. For the regulatory and economic generation improvement areas, it is generally beneficial to use parameters which can be measured on an industry-wide basis. This approach enables relative performance to be documented, and specific shortfalls in performance to be quickly pinpointed.

A typical set of such parameters, as selected by one U.S. utility, is shown in Table 1. Similar lists can be generated for non-U.S. plants. As can be seen from the table, the regulatory and economic improvements parameters are measurable on an industry-wide basis from data which is generally available within the public domain. The "Other Parameters" category encompasses performance criteria also considered important by the utility, but data for measurement of these parameters would more likely be subjective and less likely be available across the industry.

Once a suitable set of these parameters has been established, the next step is to assign weighting factors to denote the relative importance of each parameter on the list. This task is best approached by first establishing the appropriate weights in each of the three major areas noted above, and then assigning individual weighting factors to each of the parameters. For example, regulatory improvements and economic generation improvements might each carry 40% of the total weight with 20% in the "Other" category. The selection of appropriate weighting factors can be a difficult issue to decide and one which may receive a different response depending upon whom within the utility is asked the question. Therefore, it is important to develop the parameter listing and assign the corresponding weights with broad representation both vertically and horizontally throughout the utility organization. When a consensus is obtained on both the parameters and their weights, the result should be endorsed in the form of a clear statement by the utility's senior management.

TABLE 1
PERFORMANCE CRITERIA

INDUSTRYWIDE MEASUREABLE PARAMETERS

- NRC VIOLATIONS
- NRC FINES
- NRC OPEN ITEMS
- PERSONNEL EXPOSURE
- LIQUID RADIOACTIVE DISCHARGES
- GASEOUS RADIOACTIVE DISCHARGES
- RADWASTE
- EMERGENCY PREPAREDNESS

- CAPACITY FACTOR
- SCHEDULED OUTAGE DAYS INCURRED
- PLANNED VS. SCHEDULED OUTAGE DAYS
- HEAT RATE

OTHER PARAMETERS

- SITE SAFETY
- OFF-SITE SAFETY
- PUBLIC IMAGE
- REGULATORY IMAGE
- HUMAN FACTORS

The next step in the process is to assess the plant's current performance relative to each of these defined parameters. It will be necessary to gather the needed parametric data both for the plant under review and for the industry. It is generally appropriate to select two or three time periods for this evaluation. Use of several time periods will smooth out the impact of such factors as one-time events and different fuel cycle lengths. Each plant within the utility is ranked on its performance for each parameter, and an overall plant ranking is calculated. A sample result of this ranking process for one plant is shown in Table 2. With these results in hand, the utility can then define those areas in which improvement is needed. Particular attention should be paid to those areas carrying heavy weights but having poor performance. In these areas, it is especially important to understand the particular reasons why performance was poor.

As an illustration of this point, note that the plant considered in Table 2 ranked 19th out of the 22 plants evaluated in the area of capacity factor. However, the weight that the utility had assigned to this parameter was among the highest of all parameters selected. Such a result should trigger a detailed review of the specific problems which caused this poor ranking. Assistance in this type of search can be obtained through use of various industry data bases on plant performance. The General Electric Company's COMPASS data base is one such source which enables detailed comparisons to be made on either a plant-to-plant or plant-to-industry basis for a large number of plant performance areas. Table 3 is an extract from this data base and shows for one plant the capacity factor by year for the general category of reactor and fuel servicing - just one of the 23 major system categories of plant performance within the COMPASS data base. Also shown in the table is the average performance loss of all BWRs for this same category. Review of this information would specifically highlight those areas where plant capacity factor performance is in greatest need of improvement both on an absolute basis and relative to the rest of the industry. A detailed assessment of these areas can then be undertaken to develop specific corrective actions for improvement.

Similarly, once the basis for each relatively poor performance ranking of Table 2 is understood, suitable corrective actions for all identified problem areas can be determined; and improvement potential in each area can be assessed. On the basis of this improvement potential, realistic improvement goals for each performance area are then established for the next measurement period.

At this point, it may be appropriate to summarize what has been described thus far: (1) A plant-unique definition of optimum performance (goals and objectives with weighting factors) has been established; (2) Plant performance has been evaluated against this plant-unique definition in comparison to the industry; (3) Potential improvement opportunities have been identified; and (4) Goals have been established for each parameter for the next measurement period.

Now, in order to achieve these goals with limited available resources, a method must be found to prioritize all potential activities based on their individual ability to satisfy the stated goals. In fact, such a methodology is already largely developed. Since the measurement system has been developed based on the utility-specific definition of optimum performance, it follows that achievement of the goals will be optimized if activities are implemented based on their ability to increase the future overall score of the plant as measured by the total projected change for each of the individual performance parameters. Before proceeding on this basis, however, it is appropriate to review the previously established definition of optimum performance as well as the performance ranking results and consider possible adjustments to the parameter weights. Such an adjustment might be desirable in cases like that of the plant shown in Table 2 where capacity factor performance was poor, but the relative importance of this factor to the utility was high. In this case, it might be appropriate to consider a small increase to the weight assigned to capacity factor if it is judged that the increase would not significantly detract from the results desired in other areas. This adjusting process provides a way of placing greater emphasis on a specific parameter over a given time period if conditions so warrant, and a conscious decision should be made relative to the need for such an adjustment.

When an appropriate weighting system for the activity prioritization process has been agreed upon, the net benefit of each potential improvement activity is then assessed by predicting the impact that implementation would have on each of the performance parameters. The net impact on all parameters becomes the net benefit for that improvement. These predictions of performance change are best made by a team of personnel who are

TABLE 2
PARAMETER RANKINGS FOR ONE PLANT
AS COMPARED WITH 21 OTHER DOMESTIC BWR'S

PARAMETER	PLANT RANK WITHIN INDUSTRY
REGULATORY CONFORMANCE	2
NRC VIOLATIONS	6
NRC FINES	11
NRC OPEN ITEMS	8
EXPOSURE	1
LIQUID DISCHARGES	4
GAS DISCHARGES	7
RADWASTE	3
EMERGENCY PREPAREDNESS	9
PLANT PERFORMANCE	18
CAPACITY FACTOR	19
SCHEDULED OUTAGE LENGTH	8
ACTUAL/PLANNED OUTAGE	1
HEAT RATE	21
OVERALL	14

TABLE 3

CAPACITY FACTOR LOSS (%)

	YEAR 1		YEAR 2		YEAR 3	
	PLANT A	AVE BWR	PLANT A	AVE BWR	PLANT A	AVE BWR
Reactor and Fuel Servicing						
A. Shutdown and Open Vessel	0.55	1.04	0.96	0.80	1.37	0.76
B. Fuel Moving	3.01	3.11	1.74	2.37	1.64	2.08
C. Closing Vessel and Hydro	0.91	1.23	1.31	1.04	0.27	1.15
D. Startup	0.27	0.71	0.84	0.59	0.11	0.67
E. Refueling Equipment Failures	0.38	0.17	0.65	0.03	0.00	0.10
F. Other	0.00	0.00	0.00	0.00	0.27	0.03
	5.12	6.26	5.50	4.83	3.66	4.79

sufficiently cognizant to be able to judge the relative differences of all potential activities and who can draw on the expertise of others as needed. A benefit-to-cost ratio is then calculated for each potential action, and this ratio is used as the priority score. By then listing the potential actions in descending order based on priority score, those actions which most promote goal achievement at minimum cost will appear at the top of the list. To facilitate the required calculations and to assist in the program ranking and sorting routines, incorporation of the evaluation process on personal computer spreadsheet-type software is recommended. Such software will also enable ready investigation of program score sensitivities to various parameter weighting factor changes that may be needed to secure endorsement by all involved personnel.

Once all contemplated actions have been ranked, the prioritized list of activities and the associated resources needed for implementation are then matched against the resources available, and a tentative schedule is established. Using this schedule and the total projected improvement, an assessment can be made of when and how well the agreed upon goals will be achieved. If necessary (as will likely be the case), iterations can be performed until there is compatibility between the budgeted resources, the programs to be implemented, the goals, and the schedule. This built-in system of checks and balances assures that the budgeted resources are sufficient to meet the defined goals within the committed timeframe.

Periodic measurement of plant performance based on the defined parameters will provide insight on how well the overall program is working toward achieving the goals, and corrective action can be taken where needed. Furthermore, when conditions change sufficiently to so warrant, the measurement parameters and/or their weights can be changed accordingly. Thus, the overall method provides the necessary flexibility to readily accommodate the multiple and changing demands of today's environment.

PROCESS APPLICATION RESULTS

While the results of the process described above are obviously dependent on the selected definition of optimum performance, applications to-date have identified certain programs that consistently score well. Some of these programs are described briefly below:

Scram Reduction

Many plants operating today experience an excessive number of unplanned reactor scrams which unnecessarily challenge the plant safety systems and reduce plant availability. Performance can be improved through analysis of previous and potential occurrences of unplanned scrams to less than one per plant-year.

Technical Specification Improvement

The plant technical specifications for many older plants were developed at a time when relatively little plant operating experience was available. With the much broader data base that is now available, substantial improvement in levels of equipment performance can be utilized. By coupling this reliability data with current analytical methods, the plant technical specification requirements on surveillance intervals and allowable equipment out-of-service times can be optimized. These evaluations will also provide the proper balance between assurance of equipment reliability and minimizing equipment wear. Benefits thus include reduced occupational radiation exposure, reduced plant operation and maintenance costs and reduced unplanned plant scrams. Technical specification improvement evaluations at typical plants have justified extension of 1400 surveillance test intervals from monthly to quarterly and produced estimated savings in excess of $200,000 per plant-year.

High Speed Transient Analysis and Recording System

The initial startup testing at most plants included the use of a computerized, high-speed transient analysis and recording system to assist in evaluation and verification of plant system and component performance. A number of plants have found this capability to be an invaluable tool after commencement of plant operation as well. Dedicated computer hardware, software and data acquisition equipment permit accurate recording and subsequent analysis of plant transient events and aid in root cause diagnostics following off-normal conditions. Benefits accruing to utilities who have incorporated these capabilities include faster post-transient recovery, improved plant capacity factor (several days downtime savings per year), and substantial reductions in plant operation and maintenance costs.

Plant Performance Monitoring System

To optimize plant performance, early indication and correction of deviating conditions is necessary. Through the use of dedicated computer hardware, software and data acquisition equipment, on-line monitoring of key plant parameters and equipment can be accomplished. The system objective is to improve the effectiveness of predictive and preventive maintenance and thereby reduce forced outages, reduce plant operation and maintenance costs and extend component and plant life.

Refueling/Maintenance Outage Reduction

In recent years, scheduled outage time for refueling and maintenance tasks at many U.S. reactor plants has routinely exceeded 100 days per year. While major equipment modifications and replacements have accounted for some of these availability losses, other plants, faced with the same equipment problems, have managed to keep the losses at less than half that amount. Beyond the necessary management commitment, the secret to success is a well-planned and well-executed outage that makes maximum use of experienced personnel and reliable support equipment. Scheduled outage reduction provides the most fruitful area for improving plant availability and reducing plant operation and maintenance costs.

Occupational Radiation Exposure Reduction

High radiation levels in areas of the plant routinely requiring the presence of maintenance and operations personnel causes unnecessary occupational radiation exposure and inhibits worker productivity. The radiation levels within plant systems and components can be significantly reduced through application of a recently patented, field-verified process known as zinc-injection passivation. The process injects zinc oxide into the reactor water and results in reduced corrosion film buildup which, in turn, results in substantially reduced radiation levels compared to those existing on untreated surfaces. New plants and plants with new primary system piping can experience a factor of three reduction in the cobalt-60 dose rate compared to plants without the treatment. In addition to the direct reduction of occupational exposure levels, application of this process also results in reduced operations and maintenance costs.

SUMMARY

A structured process for achieving improved plant performance has been presented in which a plant-unique definition of performance is utilized to characterize the appropriate balance between regulatory, economic and other goals. Plant performance is then measured in key areas, and improvement needs are identified and prioritized. Using a built-in system of checks and balances, compatibility between budgeted resources, goals and implementation schedules is assured. By adopting such a process for use and with continued attention on upkeep and application, utilities can assure themselves that achievement of plant performance goals will be realized now and in the future.