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# Power Plant Performance

Identification of the Relationship between Availability, Reliability and Productivity

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## 1 Abstract

*Quality of electrical energy is measured by means of two categories of indices: One category is technical indices which are integrated in availability (A) and reliability (R). Another category of indices is economical which is integrated in productivity (P) index. Three mentioned integrated indices are collectively abbreviated to ARP indices and performance is a function of them. The ranges of ARP variations are vast and every country based on the level of its technological, economical and based on its social conditions should find the optimum level of the indices and then try to increase them gradually. This paper, at the level of power plant, describes the performance improvement via internal relations of the ARP indices and shows their interrelations by means of causal diagram and determines the strategies and related policies, as managerial manoeuvres, to improve the performance.*

Keywords: Performance, Availability, Reliability, Productivity, Power Plant, Strategy Policy

## 2 Introduction

Electrical energy has been the basis of economic planning for the majority of the countries in the world. Most plans intended to minimize cost and maximize availability and reliability of electrical energy to increase customer satisfaction, but they are in conflict and a trade-off could often cause one or the other to be compromised and lead to customer dissatisfaction. This paper will look closely at the inter-dependency of the above-mentioned indices and will identify ways in which optimising for one does not over compromise the other. The forthcoming sections will establish that performance is a function of availability (A), reliability (R) and productivity (P). These are referred to as ARP indices hereafter.

## 3 The Indices of Electrical Energy Quality

The quality of electrical energy, from customer point of view, is summed up into two concepts: technical and economical. Technical concept has been indicated in availability and reliability indices. The economical concept are integrated in electrical energy price which required to be in the lowest possible range. Considering the prominent role of electrical energy in the economy, it is necessary to consider the economic price, rather than pure accounting price, in our studies. Hence, the productivity instead of cost, as a more proper index, has been substituted in this study. Therefore, the managerial concepts - which are figured in the performance indices - are: availability, reliability and productivity.

## 3.1 Availability and Reliability Indices

"Availability is the probability of a device or system being in the operating or up state at a given period t in the future". (Billinton, P.67)

"Reliability is the probability of a device or system performing the purpose adequately for the period of time intended under the operating conditions encountered". (Billinton, P.59)

Above definitions are applied only to base-loaded power plant in our study. Derated states are transformed into the full load state.

It is necessary to mention that a power plant would be in one of the four following modes:

-Service mode: producing electrical energy at full load.
-Failure mode: forced out, because of a random failure.
-Maintenance mode: undergoing programmed maintenance.
-Idle mode: neither failure nor programmed maintenance, but there is not enough demand.

The above can be mathematically represented by:

$$A = \frac{ST + IT}{T} \times 100 \qquad\qquad R = \frac{ST}{ST + FT} \times 100$$

A: availability
R: reliability
ST: total time in service mode during a defined period
FT: total time in failure mode during a defined period
MT: total time in maintenance mode during a defined period
IT: total time in idle mode during a defined period
T: defined period

## 3.2 Productivity Index

Productivity is the ability to produce, and generally, it is formulated by the ratio of output to input. "Productivity improvement is a process of change " (Sumanth 84, P. 51), which is called productivity management. "Productivity management is a formal management process involving all levels of management and employees with the ultimate objective of reducing the cost of the manufacturing, distributing, and selling of a product or service through an integration of the four phases of the productivity cycle, namely, productivity measurement, evaluation, planning and improvement ". ( Sumanth 84, P.51 ) "Creating the conditions for higher performance is the essence of productivity management " ( Prokopenko 92, P. 63).

Formally, for organization productivity, two main levels of indices have been defined: the total productivity (TP) and partial productivity (PP).

In literature, the first of the above indices ( TP ) is identified to be mainstream in productivity consideration. Thus, a significant productivity analysis is focused at the level of organization, i.e. TP. ( Windle 92, p.435 ) ( Liberian 90, p.1195 ) ( Craig 73, p.13,15,20,28 ) ( Oum 92, pp.493-494,504 ) ( Hensher 92, pp.433-434 ).

In literature, the productivity at the level of organization, is formulated in different models. For the purpose of the paper, the model of Craig & Harris (Craig 73, P. 15), is chosen and its formula is as follows:

$$P_t = \frac{O_t}{L + C + R + O}$$

- $P_t$: Total productivity
- $L$: Labour input costs
- $C$: Capital input costs
- $R$: Raw material and purchased parts input costs
- $O$: Other miscellaneous input costs
- $O_t$: Total output

## 4 Interdependencies between ARP Indices

The study of interdependencies between performance indices will begin by recognition of their functional elements.

### 4.1 Functional elements of Power Plant Performance Indices (ARP)

According to the formula there are four time-dependent functional elements directly related to availability and reliability. These are service time (ST), failure time (FT), maintenance time (MT) and idle time (IT). There are also income and some cost-dependent functional elements in the productivity formula. All the income and cost-dependent functional elements are covered in the above four time-dependent functional elements, i.e. ST, FT, MT and IT.

### 4.2 Mechanisms of Change Influence

To draw the diagrams to show the change influence among the functional elements, the following remarks have been regarded:

a ) Selected functional element(s), for primary change, has been shown in the left hand side of the diagram.

b ) Positive or negative sign on the arrow ( end of vector ) means that the direction of change in the related functional element(s) are the same or different respectively .

c ) The symbols ⇙ or ⇗ mean a planned changes in functional element done deliberately.

d ) Increase or decrease in a functional element is shown by the sign of ↗ or ↙ respectively.

e ) The sign of (↙ , ↗ ) indicates it is possible that the functional element get two states during the time: decrease at first, and then increase with a delay.

Regards to the above, the mechanisms of change influence, among functional element(s) of indices, have been summarized in nine major states. Besides the nine states, although there are some other states, but the nine states are the most important and have capability to show the complexity of change influence in the functional element(s) of indices clearly and sufficiently.

The nine states have been categorised in four strategies. In each strategy, one of the most related states, has been identified.

The following diagrams show the above mentioned strategies and all of them are summarised in the change influence table ( Table No. 1 ).

S1 ) No deliberate care ( natural FT increase ):

(refer to attachment S1)

Diagram No 1

S2 ) Technical care :
( MT & FT decrease and IT increase)

(refer to attachment S2)

Diagram No 2

S3 ) Economical care
(IT decrease and ST increase)

(refer to attachment S3)

Diagram No 3

S4 Techno - Ecomical care:
( MT, FT & IT decrease )

(refer to attachment S4)

Diagram No 4

| | Policies | | | | Financial Indicators | | Outcomes | | |
|---|---|---|---|---|---|---|---|---|---|
| Strategies | ST | FT | MT | IT | Income | Cost | A | R | P |
| S1 | ↙ | ⬀ | cte | ↙ | ↙ | ↗ | ↙ | ↙ | ↙ |
| S2 | cte | ⬃ | ⬃ | ↗ | cte | ↗ | ↗ | ↗ | ↙ |
| S3 | ↗ | cte | cte | ⬃ | ↗ | ↗ | cte | ↗ | ↙ , ↗ |
| S4 | ↗ | ⬃ | ⬃ | ⬃ | ↗ | ↗ | ↗ | ↗ | ↙ , ↗ |

**Change Influence Table (CIT)**
Table No.1

## 5 Causal Diagram of Power Plant Performance Indices

The states, mentioned above, are guidelines for drawing the causal diagram of power plant performance indices.

(refer to attachment: Causal Diagram)

Causal Diagram of power plant performance Indices
Diagram No. 5

## 6 Power Plant Evaluation Approach

Regards to what are mentioned up to here, especially regards to the change influence table, performance improvement means improvement of ARP indices interdependently and it needs managerial manoeuvre on four mentioned times ( i.e. : ST, MT, FT & IT) so that in a rational duration, IT be moved toward zero and decrease in MT, FT and IT be so that the achieved income from ST increase is more than all costs belong to MT, FT and IT decrease.

## 7 Generalization

Four functional elements of ST, MT, FT and IT and managerial manoeuvre regarding income and costs are factors that the evaluation of total power grid would be possible via them. For this purpose, the total capacity of power plants, in a power grid, assumed as a single power plant and consequently all above six functional elements (ST, MT, FT, IT, Income & Cost) would be calculated and their trend curves would be drowned and evaluated.

## 8 Summary

Quality of electrical energy is measured by means of two categories of indices: technical and economical. The indices, are availability(A), reliability (R) and productivity (P) that they are referred to as ARP indices and management in power plant industry in each country, based on the level of its technological, economical and its social remarks, tries to find the optimum level of the indices and rise them gradually. In this way there are four strategies that continuous performance improvement depend on the management manoeuvres. The management manoeuvre should be orchestrated so that, the achieved income from increase ST, in mid-range period, cover all costs of the management manoeuvres and totally, assure the continuation of economical life time of the power plant. Generalization of the model for a power grid would be possible via imagination of all power plants of the power grid, as a single power plant.

## Future Researches

To put this approach in practice, based on the attitude, mentioned in this paper, the following researches - but not limited to - would be possible.

1) Development of dynamic mathematical model to test different strategies and related policies and learn the mechanisms that policies influences each other and influences the main factors of power plant.

2) Development a model of power plant performance improvement, such as: participative management model, total quality management ( TQM ) and learning model.

As ongoing research based on the paper attitude, the writers have begun a research in three power plants in IRAN. The research is being applied a learning model which has begun in Sep. year 1998 and it will be continued up to the end of year 2000. The learning model is based on five disciplines, according to what has been described in “ Senge, the firth discipline, 1990". The focus point of the model is managers' sharing in vision and related mental models. The mentioned mental models are those that make the managers capable to lead the organization in the path that they meet their shared vision.

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## ATTACHMENTS

S1 ) No deliberate care ( natural FT  increase ):

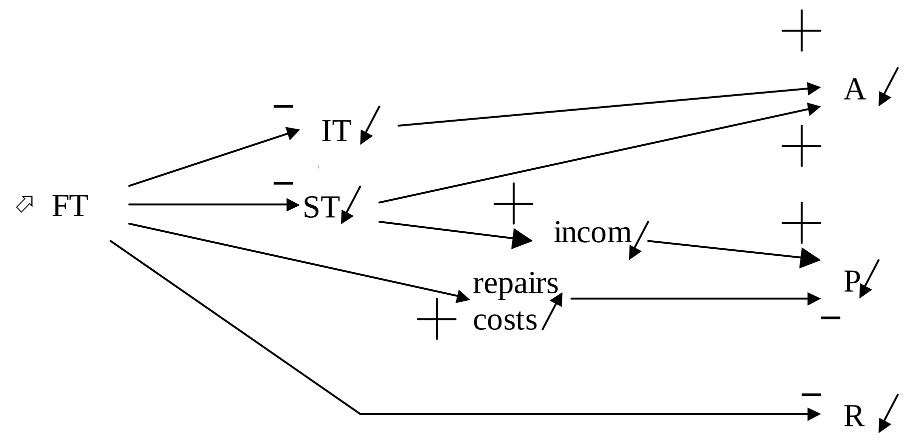


Diagram No. 1

S2 ) Technical care :
( MT & FT decrease and IT increase simultaneously)

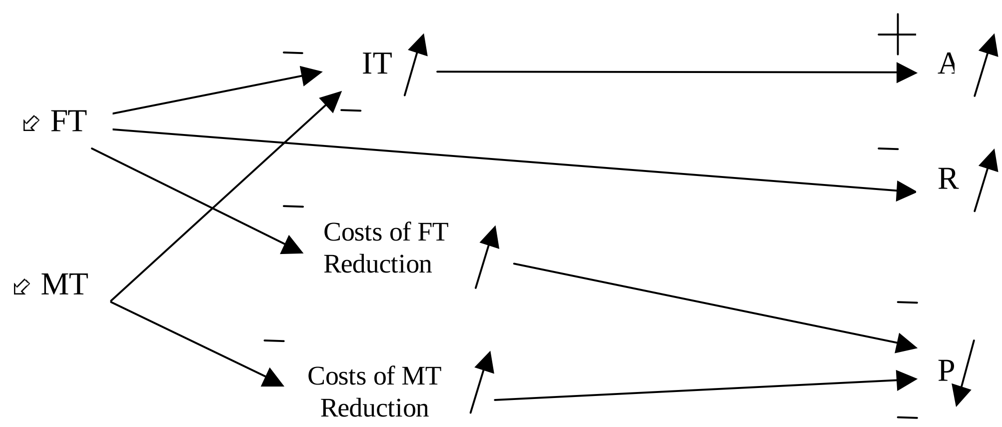


Diagram No 2

S3 ) Economical care:

(IT decrease and ST increase)

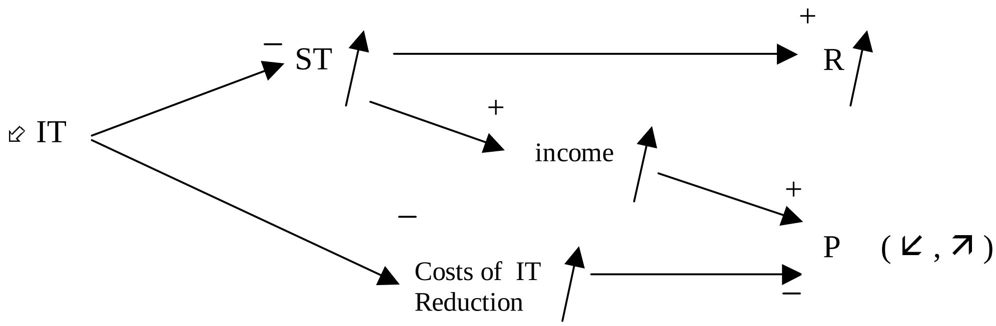


Diagram No 3

S4 Techno-Economical care :

( MT, FT & IT decrease )

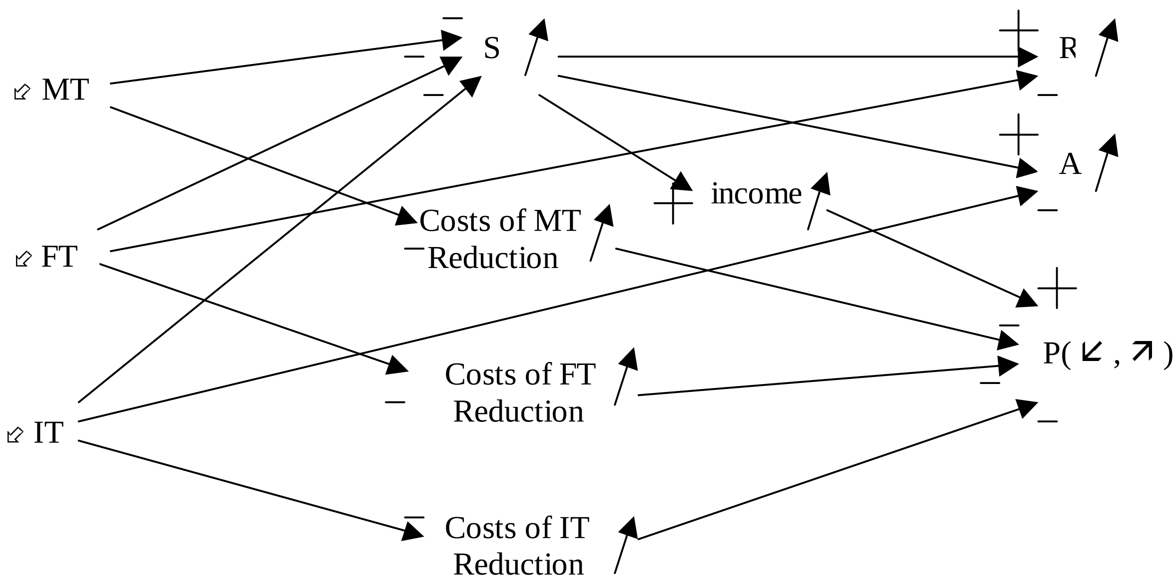


Diagram No. 4

Causal Diagram of power plant performance Indices
Diagram No. 5