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# COMPUTER NETWORK ANALYSIS OF MAINTENANCE SCHEDULE OF HYDROPOWER TURBINE

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ABSTRACT: This paper presents a Network Analysis of Maintenance Schedule of Hydropower Turbine of Jebba Hydropower Station Using Computer Software. The Performance and Management Department of the station is responsible for the scheduling of annual maintenance of turbine and its auxiliaries. This study examined the use of Power Angle (PA) software and compared it with Microsoft Office Project (MOP) software being used by the station. It was discovered that the MOSP presented the maintenance activities as arranged in table 1 without alteration, while PAS re-arranged the activities, thereby giving a more efficient order and better "Critical Path" for the maintenance activities in Jebba Hydropower Station. It was equally discovered that MOP software does not have the features to analyze the free, delay and slack for the maintenance activities, which are critical in planning and controlling of any maintenance activities or project.
KEYWORDS: maintenance, schedule, critical path method, turbine

## INTRODUCTION

Network Analysis is a generic term for a family of related techniques developed to aid management to plan and control projects. These techniques show the interrelationship of the various jobs or tasks which make up the overall project and clearly identify the critical part of the project. They can provide planning and control information on the time, cost and resources of a project. Network scheduling is a technique used for planning and scheduling large projects in the fields of construction, maintenance, fabrication and many other areas. This technique is the method of minimizing delays and interruptions by determining the critical factors and coordinating various activities. The two basic planning and control technique are Critical Path Method (CPM) and Programme Evaluation Review Technique (PERT). These methods were both developed in the late 1950s. PERT was developed under the sponsorship of the U.S. Navy Special Projects Office in 1958 as a management tool for scheduling and controlling the Polaris Missile Project. CPM was developed in 1957 by J.E Kelly of Remington Rand and M.R. Walker of Du Point to aid in scheduling maintenance shutdowns of chemical processing plants. A project must have the following features for critical path scheduling techniques to be most applicable.

i. It must have well-defined jobs or tasks whose completion marks the end of the project.
ii. The jobs or tasks are independent; they may be started, stopped and conducted separately within a given sequence.
iii. The jobs or tasks are ordered; they must follow each other in a given sequence.

The basic difference between PERT and CPM is that PERT provide three time estimate for each activity; (i) a most likely (M). (ii) Optimistic (O), (iii) pessimistic (P), which is shown below; with emphasis on the most likely.

$$Estimated \quad time = \frac{(O + 4M + P)}{6} \tag{1}$$

On the other hand, CPM uses the best estimate. This distinction reflects PERT's origin in scheduling advanced projects that are characterized by uncertainty and CPM's origin in the scheduling of the fairly routine activity of plant maintenance (Richard et al, 1998).

The effectiveness of any organization as we all know depends largely on how the management is able to manage and maintain it's resources effectively. The maintenance department is one of the greatest levers of profitability that any capital intensive organization has. An average of 40 – 50% of a capital intense industry operating budget is consumed by maintenance expenditure (www.idcon.com). Planning and scheduling are disciplined approach for utilizing your existing maintenance resources to reduce downtime and minimize the overall production costs. Maintenance management involves planned and unplanned actions carried out to retain a system or restore it to acceptable operating condition, which includes preventive, predictive, running, corrective, overhauling and breakdown and its main objectives is to ensure the highest level of availability and efficiency of plant, equipment and building in a manner required by production at an economic cost (service cost and downtime cost (Adebiyi et al, 2004).

In Nigeria, electricity generation involves two major methods namely, thermal and hydro. The hydro-power station being cheaper to run, is expected to be optimized during favorable seasons, while the thermal at other seasons come into full blast as the water levels in dams go down in hydro power stations. Jebba hydropower station was the second hydropower station in Nigeria. It was built in order to fully utilize the potentials of the Niger River. It has six units each having an output of 90MW and these brought the total installed capacity of Jebba hydropower station to 540MW (Soja et al, 2007). In order to keep these units of machine running efficiently and effectively, an overhaul of each unit of these machines is usually carried out annually (annual maintenance) which span twenty five days. The extent of the work required during an overhaul will depend to a great deal on operating conditions such as water quality and how the unit was loaded. In order for the overhaul to proceed smoothly and to accomplish all the work required, planning should start well before the overhaul starts. The effects of better planning and scheduling lead directly to increase control over the throughput of the maintenance stores.

The Department of Performance and Management used CPM as the planning and control technique for the maintenance of the station turbine and auxiliaries, since the maintenance is a routine activity. In any given project, the three factors of concern are time, cost and resource availability. There are a number of "critical path method" software packages for personal computers available to assist in setting up a flowchart. The two software packages involved in this work are MOP and PA softwares. There are other softwares which allow the schedule to be easily adjusted when unexpected delays occur. Many of these packages will also allow manipulation of the schedule based on available personnel.

In Scheduling the annual maintenance at Jebba Hydropower Station, the technical staff meets to discuss how the maintenance works should be done and what will be required during the overhauling, so that the schedule can be optimized. MOP software was used to develop the Network Diagram or Flow Chart, Gantt chart and Critical Path as shown in figures 1 to 3. The flowchart shows the order in which various tasks must take place, the time required for each task, and which tasks can be accomplished concurrently.

## ❖ MATERIALS AND METHOD

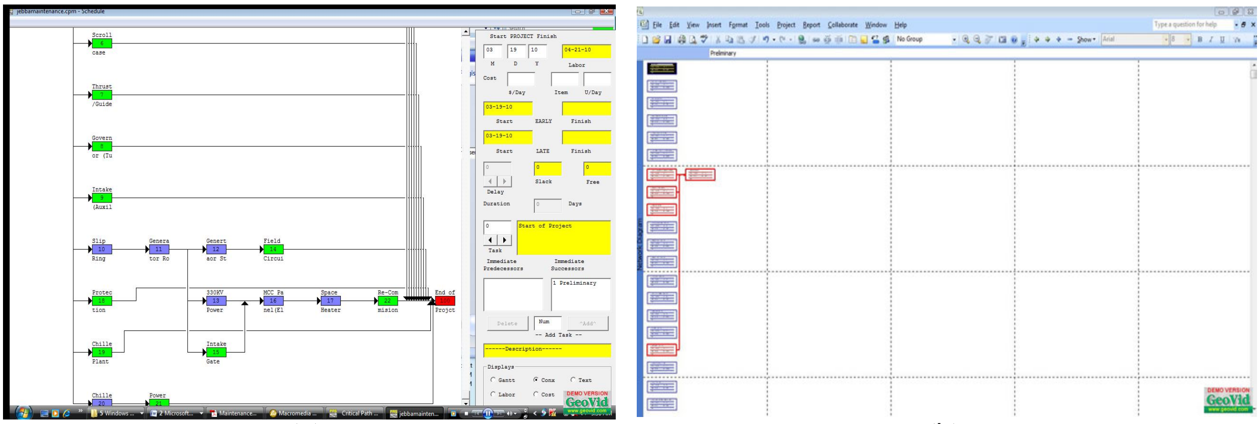
The detail maintenance schedule on each of the components of the turbine and its related auxiliaries were obtained from the Department of Performance and Management of Jebba Hydro-Electric Station and analyzed. The station has six generating units and they are coded as 2G1, 2G2, 2G3, 2G4, 2G5 and 2G6. The maintenance schedule examined in this study was meant for that of 2G2 and took place between 15$^{th}$ February – 19$^{th}$ March, 2010 except weekends.

Table 1. Activities of an Annual Maintenance of 2G2 Turbine at Jebba Hydropower Station

| S/N | Activity | Designation | Immediate Predecessor | Time in days |
|---|---|---|---|---|
| 1 | Preliminary | A | - | 1 |
| 2 | Draft Tube ( Turbine and Governor) | B | A | 18 |
| 3 | Draft Tube (Auxiliary) | C | A | 1 |
| 4 | Power Transformer (Auxiliaries) | D | A | 7 |
| 5 | Strainer Gallery (Auxiliaries) | E | A | 2 |
| 6 | Scroll case/ Turbine pit (Turbine and Governor) | F | A | 9 |
| 7 | Thrust/Guide Bearing (Governor & Mechanical W/shop) | G | A | 18 |
| 9 | Governor ( Turbine and Governor) | H | A | 13 |
| 10 | Intake (Auxiliaries) | I | A | 12 |
| 11 | Slip-Ring Compartment (Electrical) | J | A | 4 |
| 12 | Generator Rotor (Electrical) | K | J | 4 |
| 13 | Generator Stator | L | K | 6 |
| 14 | 330KV Power Transfer | M | J | 4 |
| 15 | Field Circuit Breaker (Electrical) | N | L | 1 |
| 16 | Intake Gate (Electrical) | O | K | 4 |
| 17 | MCC Panel (Electrical) | P | M,O | 3 |
| 18 | Space Heaters (Electrical) | Q | P | 3 |
| 19 | Protection and Control | R | A | 18 |
| 20 | Chiller Plant (R &A) | S | A | 4 |
| 21 | Chiller Air Handling Unit (R&A) | T | A | 2 |
| 22 | Power House Over-head Crane A/C (R&A) | W | T | 1 |
| 23 | Re - Commissioning | X | Q | 1 |

Source: - Department of Performance Management, Jebba Hydropower Station

Table 1 show the summary of the nature of work done during the maintenance period. Both PA and MOP softwares were employed to study the network diagram, Gantt chart, critical path and the task analysis ( slack, free, delay) of the activities as shown in figures 1 to 3 and table 2.



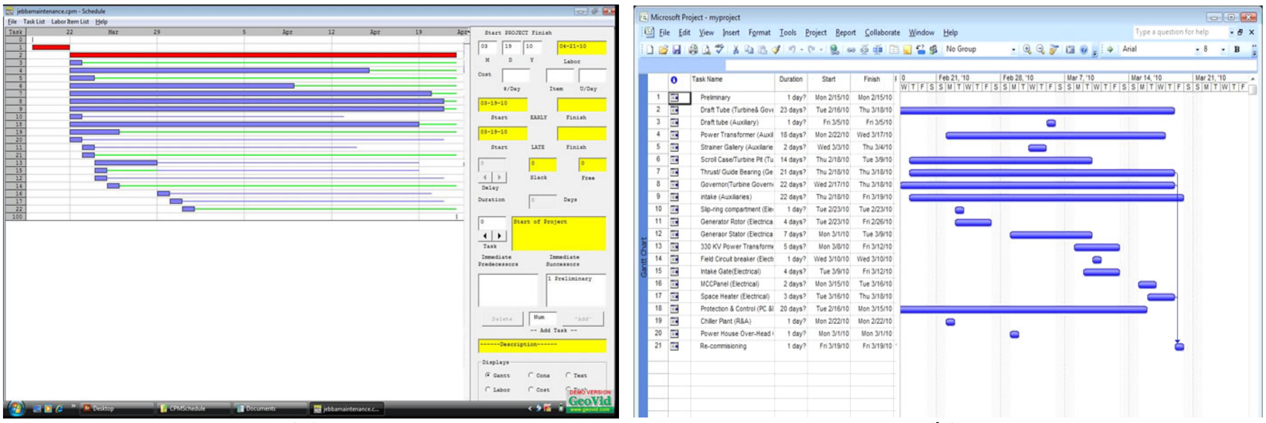
(a) (b)

Figure 1 (a) PA software Network Diagram , (b) MOP software Network Diagram

Table 2: The Task Analysis - Slack, Free, Delay and Cost obtained using PA software

| No | Description | Start - Early - Finish | | Start - Late - Finish | |
|---|---|---|---|---|---|
| 1 | Start Project | 03-19-10 | 03-19-10 | 03-19-10 | 03-19-10 |
| 2 | Preliminary | 03-19-10 | 03-19-10 | 03-19-10 | 03-19-10 |
| 3 | Draft Tube (turbine & governor) | 03-22-10 | 04-21-10 | 03-22-10 | 04-21-10 |
| 4 | Draft Tube (auxiliary) | 03-22-10 | 03-22-10 | 04-21-10 | 04-21-10 |
| 5 | Power Transformer | 03-22-10 | 04-14-10 | 03-29-10 | 04-21-10 |
| 6 | Strainer Gallery | 03-22-10 | 03-23-10 | 04-20-10 | 04-21-10 |
| 7 | Scroll Case | 03-22-10 | 04-08-10 | 04-02-10 | 04-21-10 |
| 8 | Thrust /Guide Bearing (Gov & Mec. Wkshop) | 03-22-10 | 04-19-10 | 03-24-10 | 04-21 10 |
| 9 | Governor ( turbine & governor) | 03-22-10 | 04-20-10 | 03-23-10 | 04-21-10 |
| 10 | Intake ( auxiliaries) | 03-22-10 | 04-20-10 | 03-23-10 | 04-21-10 |
| 11 | Slip Ring Compartment | 03-22-10 | 03-22-10 | 04-12-10 | 04-12-10 |
| 12 | Protection & Control | 03-22-10 | 04-16-10 | 03-25-10 | 04-21-10 |
| 13 | Chiller Plant (R & A) | 03-22-10 | 03-25-10 | 04-16-10 | 04-21-10 |
| 14 | Chiller | 03-22-10 | 03-22-10 | 04-20-10 | 04-20-10 |
| 15 | Generator Rotor( Elect) | 03-23-10 | 03-23-10 | 04-13-10 | 04-13-10 |
| 16 | Power House Overhead Crane A/C | 03-23-10 | 03-23-10 | 04-21-10 | 04-21-10 |
| 17 | 330KV Power Transfer | 03-24-10 | 03-26-10 | 04-14-10 | 04-16-10 |
| 18 | Intake gate ( electrical) | 03-24-10 | 03-24-10 | 04-16-10 | 04-16-10 |
| 19 | Generator Stator | 03-24-10 | 03-24-10 | 04-20-10 | 04-20-10 |
| 20 | Field Circuit Breaker | 03-25-10 | 03-25-10 | 04-21-10 | 04-21-10 |
| 21 | MCC Panel ( electrical) | 03-29-10 | 03-29-10 | 04-19-10 | 04-19-10 |
| 22 | Space Heater | 03-30-10 | 03-30-10 | 04-20-10 | 04-20-10 |
| 23 | Re-Commissioning | 03-31-10 | 03-31-10 | 04-21-10 | 04-21-10 |
| 24 | End of Project | 04-21-10 | 04-21-10 | 04-21-10 | 04-21-10 |

| No | Description | Slack | Free | Days | Delay | Cost | Labor | unit | Num |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Start Project | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | Preliminary | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 3 | Draft Tube (turbine & governor) | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 2 |
| 4 | Draft Tube (auxiliary) | 22 | 22 | 1 | 0 | 0 | 0 | 0 | 3 |
| 5 | Power Transformer | 5 | 5 | 18 | 0 | 0 | 0 | 0 | 4 |
| 6 | Strainer Gallery | 21 | 21 | 2 | 0 | 0 | 0 | 0 | 5 |
| 7 | Scroll Case | 9 | 9 | 14 | 0 | 0 | 0 | 0 | 6 |
| 8 | Thrust /Guide Bearing (Gov & Mec. Wkshop) | 2 | 2 | 21 | 0 | 0 | 0 | 0 | 7 |
| 9 | Governor ( turbine & governor) | 1 | 1 | 22 | 0 | 0 | 0 | 0 | 8 |
| 10 | Intake ( auxiliaries) | 1 | 1 | 22 | 0 | 0 | 0 | 0 | 9 |
| 11 | Slip Ring Compartment | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 10 |
| 12 | Protection & Control | 3 | 3 | 20 | 0 | 0 | 0 | 0 | 18 |
| 13 | Chiller Plant (R & A) | 19 | 19 | 4 | 0 | 0 | 0 | 0 | 19 |
| 14 | Chiller | 21 | 0 | 1 | 0 | 0 | 0 | 0 | 20 |
| 15 | Generator Rotor( Elect) | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 11 |
| 16 | Power House Overhead Crane A/C | 21 | 21 | 1 | 0 | 0 | 0 | 0 | 21 |
| 17 | 330KV Power Transfer | 15 | 0 | 3 | 0 | 0 | 0 | 0 | 13 |
| 18 | Intake gate ( electrical) | 17 | 2 | 1 | 0 | 0 | 0 | 0 | 15 |
| 19 | Generator Stator | 19 | 0 | 1 | 0 | 0 | 0 | 0 | 12 |
| 20 | Field Circuit Breaker | 19 | 19 | 1 | 0 | 0 | 0 | 0 | 14 |
| 21 | MCC Panel ( electrical) | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 16 |
| 22 | Space Heater | 15 | 0 | 1 | 0 | 0 | 0 | 0 | 17 |
| 23 | Re-Commissioning | 15 | 15 | 1 | 0 | 0 | 0 | 0 | 22 |
| 24 | End of Project | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |



(a) (b)

Figure (a) PA software Gantt chart and Critical Path (bar in red colour), (b) MOP software Gantt chart

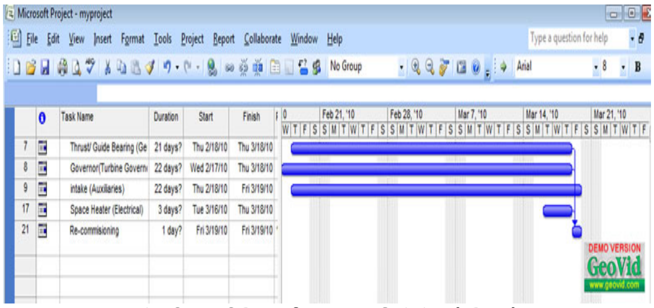


Fig 3. MOP software Critical Path

## ❖ RESULT AND CONCLUSION

The MOP software used by the Department of Performance Management presented the maintenance activities in the order in which it was listed in table 1, while PA software re-arranged the activities of the maintenance schedule as in table 1 by allowing activities 18, 19 and 20 to come before activity 11, activity 21 was equally allowed to come before activity 13 and activity 12 equally came before activity 15. It was confirmed from a technical staff of Jebba Hydropower Station that these re-arrangements are possible, since during annual maintenance, the whole system is first isolated and hence the activities are independent of each other. The effectiveness of both arrangements were evaluated and it was observed that the re-arranged activities by PA software is more efficient compared with MOP software used by the Department of Performance Management, owing to the fact that a narrower "Critical Path" was obtained from the re-arranged activities. The basis of the re-arrangement was the earliest start and earliest finish date of each activity and this gave a better free and slack task.

The Critical Path of the maintenance schedule for PA software are activities 1 and 2 as shown in figure 2a, while MOP software Critical Path are activities 7, 9, 10 and 18 as shown in figure 3. It was observed that PA software show the Critical Path along side the Gantt chart, while MOP software shows the Critical Path separately. The PA software was designed to be easy to operate, and the program assumes a Monday through Friday work week, which was the case with the annual maintenance schedule of Jebba Hydro -Power Station as it recognizes the holidays such as New Year's Day, Presidents' Day, Memorial Day, Fourth of July, Labor Day, Thanksgiving, and Christmas as non-work days. It is because of this feature that is absent in MOP software that made the Critical Path longer than necessary.

Therefore, PA software is suggested to the management of Jebba Hydropower Station as it has features that can determine the amount of delay that a task may take on without increasing the length of the project, which is called "slack". If the cost and labor are part of the scheduling activities, PA software can determine it, but because it is not part of it in this work, it is showing zero as shown in table 2.

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