International Journal of Innovation and Sustainability, 2 (2018) 41- 49
Journal Homepage: www.erjournals.com
ISSN: 0184-7937

PROSPECTS OF IMPROVED POWER EFFICIENCY AND OPERATIONAL PERFORMANCE OF KAINJI-DAM, NIGERIA

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ABSTRACT
Electricity generation of any nation serves as an engine that drives an economy of such nation. Sufficient power supply is very crucial for industrial development and economic growth of any nation. Recent studies show that most of the hydro-electric generating stations in Nigeria are operating below their installed capacity which is as a result of non-overhauling of turbines installed at the hydro power plants. This study is aimed at providing an operational efficiency analysis of Kainji hydro-electric power plant for the reviewed period of time. The considered criteria were plant availability factor, capacity factor and the overall efficiency of the plant. The study has demonstrated that availability has a very major impact on power generation and plant economy. Specific guidelines for higher flexibility in operations through quality assurance procedures and maintenance for the power station was recommended from results output summaries in relation to peer power station units for sustainable power availability. Result shows reduction in plant availability is caused by increased number and duration of forced and maintenance outages as well as prolonged maintenance periods. The causes and durations of forced outages and unscheduled maintenances were identified through the study of outage causes. The investigations ensured quantified comparative analysis for planned and unplanned outages by using results to estimate unit generators' performance. The study in a nutshell gives suggestions that could help improve power efficiency in Kainji and other hydropower plant stations in Nigeria.

Keywords: Power Efficiency, Operational Performance, Hydro-Electric Power, Electricity Generation, Plant Availability Factor, and Capacity Factor

INTRODUCTION

In Nigeria today, little seems to be known about the theoretical basis of deregulation in the electricity industry. This is because knowledge of it is still very limited. In this regards, the restructuring processes have brought about new problems and many open questions, especially regarding the introduction of competitive mechanisms and their effects on the availability of power supply. In dealing with these uncertainties, it is required that the electricity generation industry have some basic knowledge, no matter how little, about issues that could affect performances of power generation in order to enhance reliability and availability.

How to cite this article: Madu; K. E. (2018). Prospects of improved Power Efficiency and Operational Performance of Kainji-Dam, Nigeria. *International Journal of Innovation and Sustainability*, 2: 41-49.

The increasing competition in the electricity sector has had significant implications for plant operations; it requires thinking in strategic and economic rather than purely technical terms. The new order is requiring new and more appropriate measures that link technical performance with financial results. The facilitator for this new interest in reliability measures will be the evolving market-based business environment ushered in by the need of customers for lower electricity prices to help them meet the demands of the presumably competitive electricity market economy. Commercial Availability is one measure that has evolved to meet that need of the present power management and has been successfully adopted by numerous countries and companies around the world. The challenges of energy production vary from nations to nations even when they are open to many choices as per type and regulation. While rapidly growing economy like Nigeria is hungry for practical supply of any power to support economic growth and provide basic energy services to her people, the industrialized nations of the world are focusing on ensuring secured electricity supplies at competitive prices also in an environmentally acceptable way.

The Nigerian power generation capability has nosedived to an abysmal level, particularly at the generation stations due to unavailability. In recent past, Nigeria has been referred to as a 'Nation that has Covenant with Darkness' by the Tell Magazine July 27, 2009. They were not far from the truth as a country with a population of over 140 million people had only 1500 MW of electricity to share at that time. This was put at 15.58 kW per individual per annum by the Central Intelligence Agency, (CIA 2007 fact book). That is about 1500MW total generation. Nigeria ranks abysmally low compared to other countries of Africa. In order to achieve notable power generation capability, compulsory availability data documentation is crucial.

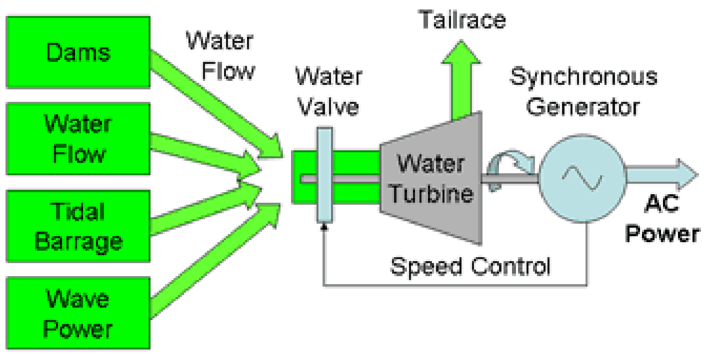
BRIEF HISTORY OF KAINJI DAM

Kainji Dam is a dam across the Niger River in Niger State of Northern Nigeria. Construction of the dam was carried out by impregilo (a consortium of Italian Civil Engineering Contractors) and designed by Joint Consultants, Balfour Beatty and Nedeco, and began in 1964, was completed in 1968. The total cost was estimated at US209 million, with one-quarter of this amount used to resettle people displaced by the construction of the dam and its reservoir. Kainji dam extends for about 10 kilometers, including its saddle dam, which closes off a tributary valley. The primary section across the outflow to the Niger is 550 meters (1,800 ft). Most of the structure is made from earth, but the center section, housing the hydroelectric turbines, was built from concrete[1]. The section is 65 meters (213 ft) high. Kainji dam is one of the longest dams in the world. Construction work on Kainji Dam took off in 1964 and lasted for four years. By 1968, it was ready for commissioning with 4 sets of Kaplan turbines, Units 7, 8, 9 & 10 of 80 MW each totaling 320 MW. The station was officially commissioned in February 1969. In 1976, two additional sets of Kaplan turbine, Units 11 & 12 of 100 MW each were installed, bringing the installed capacity of the station to 520 MW. To further increase the installed capacity, two additional sets of fixed blade or base load machines were installed. Units 5 & 6 of 120MW each, making the total installed capacity of the station to be 760 MW in 1978. For convenient hydrological operation, River Niger is divided into Upper Niger, Middle Niger and Lower Niger. Kainji Dam is located on the middle Niger. At this area, it is fed by many tributaries such as R. Malando, R. Danzaki and R. Sokoto/ Rima etc. Kainji reservoir experiences two dual flood regimes, i.e. black and white floods. Back water effect of the reservoir can be felt as far back as Kawara Village after Yauri in Kebbi State. Measurement of rise and fall of Lake Elevation on daily basis is a hydrological priority. The station steps up voltage from 16 kV to 330 kV to the national grid[2]. Electricity is transmitted from the transformer deck through 6 x 330 kV lines to the switchyard. Each line at the switch yard has Sf6 breaker to break circuit when there is fault. Units 1, 2, 3, & 4 are open pits fervently awaiting the installations of additional four machines to beef up power generation. The dam generates electricity for all the large cities in Nigeria. Some of the electricity is sold to the neighboring country of Niger. In addition, occasional droughts have made the Niger water flow unpredictable, diminishing the dams electrical output[8]. The design and purpose of the dam included power production, progressive development of navigation, flood control in the Niger Valley and fishery production of over 10, 000 tons annually. The Niger River is regulated by controlling the discharge rates through both the generating turbines and the spillways.

Hydroelectric Power

Hydro-electric power, using the potential energy of rivers, now supplies 17.5% of the world's electricity (99% in Norway, 57% in Canada, 55% in Switzerland, 40% in Sweden, 7% in USA). Apart from a few countries with an abundance of it, hydro capacity is normally applied to peak-load demand, because it is so readily stopped and started. It is not a major option for the future in the developed countries because most major sites in these countries having potential for harnessing gravity in this way are either being exploited already or are unavailable for other reasons such as environmental considerations. Growth to 2030 is expected mostly in China and Latin America[3].

Hydro energy is available in many forms, potential energy from high heads of water retained in dams, kinetic energy from current flow in rivers and tidal barrages, and kinetic energy also from the movement of waves on relatively static water masses. Many ingenious ways have been developed for harnessing this energy but most involve directing the water flow through a turbine to generate electricity.

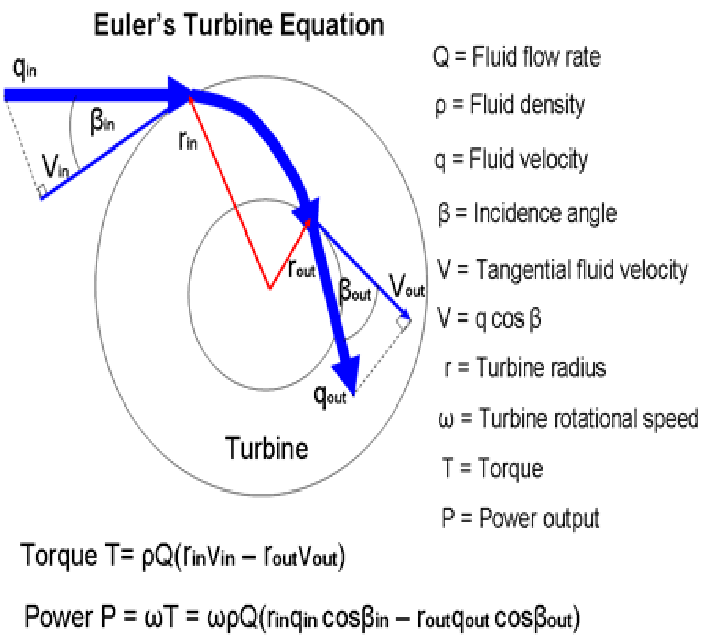


Hydro Electric Power Generation

Water Turbines: Like steam turbines, water turbines may depend on the impulse of the working fluid on the turbine blades or the reaction between the working fluid and the blades to turn the turbine shaft which in turn drives the generator. Several different families of turbines have been developed to optimize performance for particular water supply conditions.

Turbine Power Output: In general, the turbine converts the kinetic energy of the working fluid, in this case water, into rotational motion of the turbine shaft.

Swiss mathematician Leonhard Euler showed in 1754 that the torque on the shaft is equal to the change in angular momentum of the water flow as it is deflected by the turbine blades and the power generated is equal to the torque on the shaft multiplied by the rotational speed of the shaft. See following diagram.



Note that this result does not depend on the turbine configuration or what happens inside the turbine. All that matters is the change in angular momentum of the fluid between the turbine's input and output.

Hydroelectric Power Generation Efficiency: Hydroelectric power generation is by far the most efficient method of large scale electric power generation. See Comparison Chart. Energy flows are concentrated and can be controlled. The conversion process captures kinetic energy and converts it directly into electric energy. There are no inefficient intermediate thermodynamic or chemical processes and no heat losses. The overall efficiency can never be 100% however since extracting 100% of the flowing water's kinetic energy means the flow would have to stop. The conversion efficiency of a hydroelectric power plant depends mainly on the type of water turbine employed and can be as high as 95% for large installations. Smaller plants with output powers less than 5 MW may have efficiencies between 80 and 85 %. It is however difficult to extract power from low flow rates.

Note: The theoretical Betz conversion efficiency limit of 59.3% which represents the maximum efficiency which can be obtained from a wind turbine, does not apply to hydraulic turbines since there are many variations in turbine designs and more possible controls of the water flows. This means that there are equivalent variations in potential turbine efficiency, many of which can exceed the Betz limit.

Turbine Types

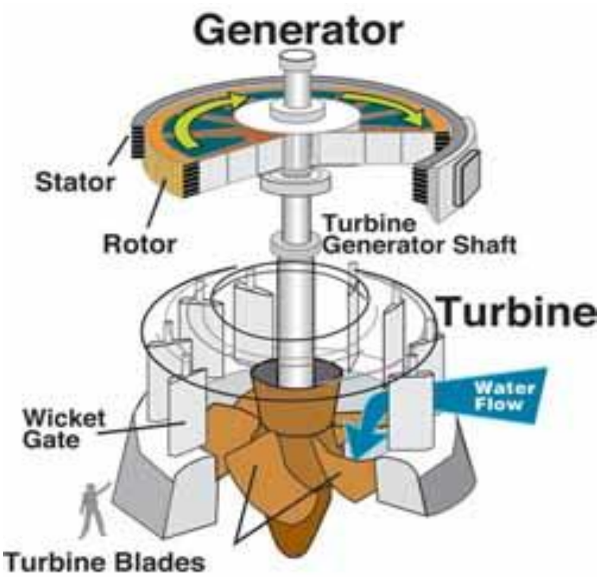
The most appropriate turbine to use depends on the rate of water flow and the head or pressure of water.

Impulse Turbines. Impulse turbines require tangential water flow on one side of the turbine runner (rotor) and must therefore operate when only partly submerged. They are best suited to applications with a high head but a low volume flow rate such as fast flowing shallow water courses, though it is used in a wide range of situations with heads from as low as 15 meters up to almost 2000 meters.

Pelton Turbine. The Pelton turbine is an example of an impulse turbine. High pressure heads gives rise to very fast water jets impinging in the blades resulting in very high rotational speeds of the turbine. The split bucket pairs divide the water flow ensuring balanced axial forces on the turbine runner. Pelton wheels are ideal for low power installations with outputs of 10kW or less but they have also been used in installations with power outputs of up to 200 MW. Efficiencies up to 95% are possible.

Reaction Turbines: Reaction turbines are designed to operate with the turbine runner fully submerged or enclosed in a casing to contain the water pressure. They are suitable for lower heads of water of 500 meters or less and they are the most commonly used high power turbines.

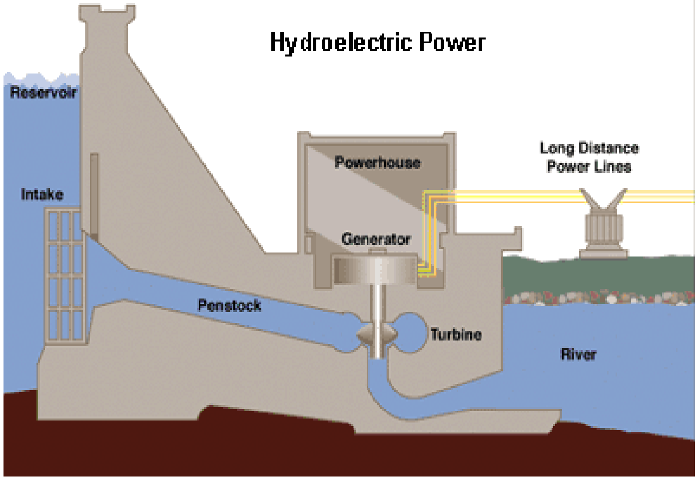
Francis Turbine: The Francis turbine is an example of a reaction turbine. Water flow enters in a radial direction towards the axis and exits in the direction of the axis. Large scale turbines used in dams are capable of delivering over 500 MW of power from a head of water of around 100 meters with efficiencies of up to 95% power from Dams (Potential Energy).



Source U.S. Army Corps of Engineers

A hydroelectric dam installation uses the potential energy of the water retained in the dam to drive a water turbine which in turn drives an electric generator. The available energy therefore depends on the head of the water above the turbine and the volume of water flowing through it. Turbines are usually reaction types whose blades are fully submerged in the water flow.

The diagram above shows a typical turbine and generator configuration as used in a dam.



Source: TVA

The civil works involved in providing hydro-power from a dam will usually be many times the cost of the turbines and the associated electricity generating equipment. Dams however provide a large water reservoir from which the flow of water, and hence the power output of the generator, can be controlled. The reservoir also serves as a supply buffer storing excess water during rainy periods and releasing it during dry spells.

The buildup of silt behind the dam can cause maintenance problems.

Available Power

Potential energy per unit volume = ρgh

Where ρ is the density of the water (10^3 Kg/m^3), h is the head of water and g is the gravitational constant (10 m/sec^2)

The power P from a dam is given by, P = ηρghQ

Where Q is the volume of water flowing per second (the flow rate in m^3/second) and η is the efficiency of the turbine. For water flowing at one cubic meter per second from a head of one meter, the power generated is equivalent to 10 kW assuming an energy conversion efficiency of 100% or just over 9 kW with a turbine efficiency of between 90% and 95%.

"RUN OF RIVER" POWER (KINETIC ENERGY)

"Run of river" installations are typically used for smaller schemes generating less than 10 Megawatts output. Water from a fast flowing river or stream is diverted through a turbine, often a Pelton wheel which drives the electrical generator. The head of water is essentially zero and the turbine converts the kinetic energy of the flowing water into the rotational energy of the turbine and the generator. The available energy, therefore, depends on the quantity of water flowing through the turbine and the square of its velocity. Impulse turbines which are only partially submerged are more commonly employed in fast flowing run of river installations while in deeper, slower flowing rivers, submerged Kaplan turbines may be used to extract the energy from the water flow Run of river projects are much less costly than dams because of the simpler civil works requirements. They are, however, susceptible to variations in the rainfall or water flow which reduce or even cut off potential power output during periods of drought. During flood conditions the installation may not be able to accommodate the higher flow rates and water must be diverted around the turbine losing the potential generating capacity of the increased water flow. Because of these limitations, if the construction of a dam is not possible, run of river installations may need to incorporate some form of supply back-up such as battery storage, emergency generators or even a grid connection.

MATERIAL AND METHOD

The consistent dearth in power generation and supply in Nigeria has, hitherto, been a matter of utmost concern. The prospects of improved power efficiency may be said to be an expectation or a looking forward, to improve the power efficiency in kainji dam. This end can be achieved through numerous ways, which include:

Load factor
Bypass
Increase in pressure head
Operational movements
New technologies
Electricity market opportunities
Power efficiency
Energy efficiency

Load Factor: Load factor in essence means efficiency it may be defined as the ratio between the actual energy generated by the plant to the maximum possible energy that can be generated with the plant working at its rated power and for duration of an entire year.

Bypass: To improve the efficiency of a hydroelectric power plant, multiple processes can be combined to recover and utilize the residual heat energy is hot exhaust gases. In combined cycle mode, power plant can achieve electrical efficiencies up to 60 percent. The term "combined cycle "refers to the combining of multiple thermodynamic cycles to generate power.

Operational Improvement: Existing power plants are eligible for several operational changes. The report finds that plant optimization could increase the performance of these plants and raise revenue for power plant operators. Markets could also be adjusted to allow hydropower to complete as a flexible reserve to manage variability and decrease cycling of thermal plants. Again, there is out value added from increasing the use of reserves, although the monetary trade-off between decreasing wear and tear on thermal plants and increasing use of hydropower plants is unclear. Another operational change could be compensating hydropower for providing reliability and security to the grid, which would increase income to each plant by about 40%.

New Technologies: Making mechanical and technological changes to hydropower fleet can also increase value for examples; the report finds that expanding the operating range of the plant can increase the income of that plant by 61%. In layman's term, "expanding the operating range" just means altering the technology to serve lower loads and high peaks, as a percentage of capacity. Upgrading plants to have variable or those units to meet different kind of demand including more rapid response and variability management. This change could increase each plants income by around 85%. Finally, plants can be constructed to be "closed-loop" (or adjacent to waterways) to cut down on permitting time and minimize environment at impacts.

Electricity Market Opportunities: Changes in the management of electricity markets would also create more opportunity for hydropower. Sub-hourly scheduling encourages wider participation and flexibility compensation for scheduling in forward markets. The report also notes that bringing more demand response to market would help allow all generators including hydropower or to receive competitive energy and ancillary services prices. All things being equal, these changes could lower electricity price by 5%. Independent systems operators (ISO'S) scheduling hydropower resources over several hours/days would also allow for optimization of hydropower in the context of other resources. The fixed-schedule approach could increase profits from plants between 63 and 77 percent. Why? Because the current market structure benefits fossil fuel generators, whose output is time independent. It doesn't matter the day/hour. They can burn fuel to generate electricity. Pumped hydro or energy limited hydro does not have this advantages and instead guesses at the lowest cost time to ''refined'' and the highest price time sell.

Power Efficiency: Power efficiency is the ratio of the output power divided by the input power.

Energy Efficiency: Energy efficiency is defined as the ratio of the output energy divided by the input energy.

The Averages Overall Summary of Total of All Parameters and Indices for Kainji Power Station

Table1: Overall summary of Averages of Kainji Power Station Indices and Parameters

Generator Parameters Analyzed	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11	Unit 12	Station Sum	Averages
Availability for 2004-2011	0.00	88.24	54.51	80.67	89.50	85.15	93.03	85.98	577.08	72.13
Availability Factor for 2004-2011	0.00	88.24	54.51	80.67	89.50	85.15	93.03	85.98	577.08	72.13
Equivalent Availability for 2004-2011	0.00	84.99	53.35	78.93	78.93	71.22	84.38	76.43	505.53	63.19
Forced Outage Factor for 2004-2011	0.00	10.53	7.28	91.44	7.06	12.26	5.88	28.22	162.66	20.33
Service Factor for 2004-2011	0.00	83.56	52.37	77.32	80.57	82.24	88.03	69.05	533.13	66.64
Starting Reliability for 2004 - 2011	0.00	93.64	76.56	99.31	95.22	89.30	94.94	89.25	638.22	79.78
Planned Outage Factor for 2004 -2011	0.00	1.23	0.35	12.01	3.44	2.59	1.09	2.68	23.41	2.93
Capacity Factor for 2004 -2011	0.00	0.81	0.51	0.76	0.65	0.61	0.82	0.61	4.77	0.60
Forced Outage Rate for 2004-2011	0.00	11.06	44.26	31.64	8.40	13.04	6.34	6.34	139.75	17.47
Partial Forced Outage, Pf, for 2004-2011	0.00	0.95	0.62	0.96	0.90	0.97	0.95	0.80	6.14	0.77
Full Forced Outage for 2004-2011	0	0	0	0	0	0	0	0	0	0.00
Equiv. Forced Outage Rate for 2004-2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maintenance Factor for 2004-2011	0.00	34.47	43.87	1.83	14.71	5.54	19.27	14.15	133.84	16.73

Kainji Hydro Power Station: Major Causes of Outage and Unavailability Summarized from Outage Data Records

The major interpretations for various graphical presentations which includes description and causes of various major outages (Which includes seasonal changes, Planned outage, Maintenance Outage, Forced outage) of the Eight (8) generating units within the period of investigation are as listed below. Such Graphical movements as seen are: Increase, Decrease and Plateau etc. some of these events are repetitive and were summarized. For every increase it is either steady rise, sharp rise, an upward, trend, or a boom (a dramatic rise) and for every decrease either a decline, steady fall, sharp drop, a lump (a dramatic fall), or a reduction. Plateau normally levels out, does not change (steady), remained stable or stayed constant (maintained the same level). Section 4.8.12 explains the entire characteristics based on the operational

records collected from the power station. Majorly, this section complements the outage reasons given by the National Center, NCC amongst some of the reasons for the outages are as detailed below.

Some of the major events are damaged Turbine Pit occasioned by governor failure as well as turbine runaway which led to the damage of the unit 1G5. It is currently undergoing rehabilitation by the World Bank, under the World Bank assisted programme. Joint Monthly Inspection, Generator serious haunting (continuous load deflection from zero to 65MW), Tripping on Master G1& G2 and rotor earth fault, 40x and Auxiliary timer, Separation for back feed to Shiroro Generation Station, Over current voltage control trouble, high water leakages from the throat ring, Shut down for frequency regulation by NCC order, contamination of the main bearing oil, high water level in the turbine pit due to submersible pumps failures, upper guide high temperature, emergency shutdown due to loss of control, Shut down for Jebba lake level regulation, governor oil duplex filter trouble, under- water inspection of by divers, system disturbance, replacement of burnt dash pot solenoid, Tripping on Circuit breaker lockout and MCB trip. Tripped on reverse power, serious oil leakage from thrust bearing sump, governor oil pumps failures, sheared guide vane arm gear pin, topping up intake gate 'A' oil sump, draining of the exciter tube accumulated with oil Tripped on start block subs I & II and field breaker abnormal close, faulty return motion cable, Governor oil pumps failure, Restricted earth fault relay, transferring of unit auxiliary load from 'B' side to 'A' side of the station services system, smoking Blue phase Current Transformer, Shut down to deaden 330KV reserve bus for the purpose of isolating 1x205 330KV breaker on lock out, burnt exciter slip ring bolt and nuts, MMS fixing of sheared Head-cover stuffing box bolts, air coolers trouble, Intake gate leakage fault, Tripped on stator winding temperature phase 1 high alarm, 16kV breaker fault, current limitation 404 amps trip, under impedance, governor system proportional valve washing, thrust bearing heat exchangers high temperature, draining of its exciter tube oil, head cover pump failure, head cover sump high water level, operation on SS17 and 11kV/415V transformer, high thrust bearing temperature 83.5oC, stator earth fault trip, and EMS replacement of punctured stator coils, SSB Transformer connection to the 16kV Network, decoupling of isolator 7A3b permanent links for a work permit on SSB, Draining of accumulated oil in the runner tube, lower guide bearing temperature high (77 ^{o}C).

RESULTS AND DISCUSSION

Kainji Hydro Power Plant had most of its failures related to frequent outages occasioned by, both issues within plant management control and outside plant management control. Majority of the reasons within and without plant management control being are as given in the outage reasons (previous section)[7]. The inference drawn here, are from a combination of the graphical output result trend and the output results presented in tables above. The Availability of the units peaked at various times of the years as seen in the Tables. 1G6 peaked at 96.03% in 2008, 1G7 peaked at 97.86% in2007, 1G8 peaked at 99.36% in 2006, 1G9 peakedat98.55% in 2004, 1G10 peaked at 97.31% in 2004, 1G11peaked at 96.81% in 2004, and 1G12 peaked at 90.80% in2007. In the year 2006 1G8 had the highest yearly availability of 99.36%. The year 2007 recorded the highest station average availability of 91.88% while the Station's average for the period under review is 96.18%. Unit 1G5 recorded a low of 0.0% availability throughout the period under review due to damaged stator winding and turbine pit and has not come back as at the time of this writing. Each of the units had their lowest availability values as thus: 1G5 had 0.0% all through the years as said earlier,1G6 had 69.75% in 2004, 1G7 and 1G10 had a low of13.69% and 68.22% respectively in 2008, 1G8 had a low of 21.48% in 2005, 1G9 has 72.73% in 2006, 1G11 had91.06% in 2009, and 1G12 had a low of 57.10% in 2004respectively. Besides availability, the Equivalent Availability Factor which indicates that both full forced outage and deratings which has characterized the entire units has been considered in the evaluations and also shows that availability is limited majorly by these forced outages and many operational issues. The graphical results also followed the same trend as seen from the graphical result in the above section.

Findings

The failure rate which is a determinant of reliability and availability is a reasonable measure for stability of generating units and indication for economical effectiveness of repairs. Generally, although some of the units showed strengths in some years, the trend of availability fluctuated greatly within the period of investigation this affected the average availability and on the average, could not get to the expected benchmark within the seven year span of investigation. The differences in the values obtained can be associated to the operational profiles of the various units and majorities are also non-operational[4]. From the output results tables, equivalent availability values were almost the same with availability values. In reality (i.e. when output data is correctly reported), both differ greatly with about 20%variability. Again, full factor and EFORD which forms good measurement indices (particularly outages during demand) recorded zeros throughout the years. This is as a result of incoherent data recording system in place. There were identifiable areas of data manipulations in the outage records during the data arrangements against the different parameters. This might obviously have contributed to the high values obtained which are different from the realities.

On the overall, there is a trend in availability and other indices and parameters because they fluctuated greatly within the period of investigation and on the average, could not reach up to the expectations. When we reconcile these results output values to the parameters and indices definitions and implications on generators[5], it becomes clear that some of the units' generators performed below potentials. The high values of availability and other parameters were due to fact that full and prorated partial forced outage hours are not accounted for. However, it is likely that the time to restore a unit to full capability would average more than five hours for a single generator during demand periods. It is much more probable that the total forced outage hours would be several times higher (some previous studies suggest that the average restoration time for a gas turbine forced outage is on the order of 24 hours for base loads)[4].

However, Equivalent availability is another index considered very effective in this regards. It is another measurement which can be tracked based on outage reporting style; it has become increasingly popular in the new power performance measurement. This is not same with the traditional time-based availability measurement expressed above[6]. Equivalent availability considers the lost capacity effects of partial equipment deratings and reports those effects as Equivalent Unavailable Hours[6]. For example, if a unit operated for 100 hours with an equipment limitation at 80% of nominal rated capacity, it would be considered to have accrued 100 Hours x 20% derating = 20 equivalent derated hours. For operating hours of 100 hrs the traditional (time-based) Availability would show as 100%; but, the Equivalent availability would equal 100 available hours minus the 20 equivalent derated hours for a measure of 80% [6]. This parameter could however not be used because incomplete data recording style observed generally in this power stations.

For a good and balanced power generation system, the availability requirements should be as follows: The unit Generator should be = 97% which means a maximum of 11 days in a given year period of unavailability for reason of unplanned repair or maintenance etc. The important components of the unit generator should have availability of 94% minimum. The fuel supply should have the availability of 99.5% etc. but these were not the case in the study results. The evaluation of power plant performance is one of the most important tasks at any power station. Without its availability records, the plant staff and stakeholders cannot determine ways to improve performance of the equipment and make the plant profit-oriented for plant owners. The causes of unavailability must be thoroughly analyzed to identify the areas for generators performance improvement. This study provides some corresponding levels of potential and cost-effective improvements from the use of performance parameters to improve unit availability. This can be justified by using the Richwine Model of Electricity Generation Standards to analyze the subject of availability.

CONCLUSION AND SUGGESTIONS

The inherent energy availability of power generation units in Kainji Hydro Power station in Nigeria has been investigated. Some possible causes of unavailability have been identified. Ways to overcome the causes comparable to international peers have been presented. The results of analysis have justifiably outlined the areas of weakness in the power station. The study has touched areas of availability likely to be encountered by power plants generation managers in other stations in Nigeria. Generally, the facts presented alone in the study are sufficient to exhibit the importance of power availability and performance measurement in enhancing the Nigeria's energy revolution and development. This work challenges the widespread practice of abuse in the use of relevant parameters and indices for the determination of generator performance improvements for a healthy electricity supply, profitability and sustainability in the station and in Nigeria in general. The analysis is self-contained and gives a useful practical introduction to standard availability performance evaluations and monitoring.

Following the above synopsis, we derive the suggestions herein, which if implemented, would make a difference in Kainji power plant and electricity distribution in Nigeria:

The power station should align in the development of very well enhanced equipment specific Operations and Maintenance (O & M) procedures programs.

The power station should embrace the use of powerful software for analyses of the various performance parameters and indices. The result will be beneficial in the exchange of information and monitoring of station units performance trend allowable for improvement of performance of power generating assets in the station and to improve the quality of life of its users.

Load growth should be monitored locally from the station based on subsequent demand rates and frequency. This will help regulate incidences of system collapses.

Generally, the regulatory authority should benchmark the unit generators in the power industry. The benchmarking philosophy will help Nigeria to achieve the following if properly implemented:

- Set realistic, achievable goals
- Identify best areas for potential improvement
- Give advance warning of threats
- Trade knowledge and experience with peers
- Quantify and manage performance risks
- Create increased awareness of the potential for and the value of increased plant performance.

There is need to set up a well-equipped effective efficiency department for data collection and analysis using the applicable KPIs and standards. The results of analysis and study will help to enable us have a good planning system in the station. The data collection and monitoring should align with the

industry requirement to enable all the power plants harmonize reporting standard and procedure.
The plant design organizations should henceforth provide increased engineering support to the operating plants staff particularly during design upgrade projects. This is very important in Nigeria as we seek to upgrade most of the old power plants either to increase availability or dependable capacity.

Management should endeavor to adhere to international best practice and standards in staff recruitment and rewards.
Adequate structure should be put in place to monitor load growth nationwide.

The empty penstock awaiting installation of new machines should be implemented urgently rather building new capacities from the beginning.

Overhaul and extensive maintenances is recommended for all the units, particularly those above 25-years of operations or those above the operating numbers of running hours and megawatts generation specified for overhaul.

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