Development of Standard Operating Procedure for a Combined Cycle Power Plant: A Case Study

by

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DECLARATION

This is to certify that the thesis work entitled "Development of Standard Operating Procedure for a Combined Cycle Power Plant: A Case Study" has been carried out by K.M.M. Resalat Rajib in the Department of Industrial Engineering and Management, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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ABSTRACT

This study is carried out to understand the effect of Standard Operating Procedure (SOP) in a Combined Cycle Power Plant (CCPP). We chose Khulna 225MW CCPP as the study field. The study is qualitative rather than quantitative in nature. Initially, operational system practiced in this power plant was observed closely by participating with the operation team. Afterwards, for some selective jobs SOP was developed, tested, corrected and released for practical implementation. Sufficient training was conducted to habituate the operator for using the SOP. Then a survey was carried out to understand the effect of SOP.

In most of the cases outcomes of the study is in-line with the expected outcomes assumed initially during the study. That is, SOP is helpful to ease the operational process, to uniform the operational activities, to improve compliance related to organizational policy, HSE and Legal Issues, to reduced trouble in decision making and to increase plant availability factors in long run. However, some operators opined that in some cases SOP is not significantly helpful and some operators found SOP makes no difference on some points. Operators with more experience opined in every case that SOP is significantly helpful for reducing human error.

CONTENTS

LIST OF FIGURES

NOMENCLATURE

BOP	Balance of Plant
BPDB	Bangladesh Power Development Board
CCPP	Combined Cycle Power Plant
CI	Combustion Inspection
DEH	Digital Electro-Hydraulic
EDG	Emergency Diesel Generator
EH	Electro-Hydraulic
EMD	Electrical Maintenance Department
EPC	Engineering Procurement & Construction
FG	Function Group
FWP	Feed Water Pump
GCB	Generator Circuit Breaker
GOB	Government of Bangladesh
GT	Gas Turbine
HEART	Human Error Assessment and Reduction Technique
HGPI	Hot Gas Path Inspection
HMI	Human-Machine Interface
HP	High Pressure
HRSG	Heat Recovery Steam Generator
HSE	Health, Safety and Environment
HVCB	High Voltage Circuit Breaker
I&C	Instrumentation and Control
I/A	Instrument Air
IP	Intermediate Pressure
ISO	International Organization for Standardization
JAM	Junior Assistant Manager
JOP	Jacking Oil Pump
KPa	Kilo Pascal
LOTO	Lock Out Tag Out
LP	Low Pressure
MCL	Maximum Continuous Load

MMD	Mechanical Maintenance Department
MOV	Motor Operated Valve
Mpa	Mega Pascal
MW	Mega Watt
NLDC	National Load Dispatch Center
NWPGCL	North-West Power Generation Company Limited
O&M	Operation and Maintenance
OCGT	Open Cycle Gas Turbine
OEM	Original Equipment Manufacturer
OHSAS	Occupational Health and Safety Association for Healthcare
OLTC	On Load Tap Changer
P&ID	Piping and Instrumentation Diagram
PDCA	Plan-Do-Check-Act
PTW	Permit to Work
SDE	Sub Divisional Engineer
SFC	Static Frequency Convertor
SOP	Standard Operating Procedure
SSD	Static Starting Device
ST	Steam Turbine
TAT	Temperature After Turbine
TG	Turning Gear
TQM	Total Quality Management
TSI	Turbine System Interface
WTP	Water Treatment Plant

CHAPTER 1: INTRODUCTION

1.1 POWER SECTOR OF BANGLADESH

The utmost important requirement of the current civilization is energy in the form of electrical power, mainly produced in power plants. At present, we could not even imagine this world without electrical power for a moment. Hence, the importance of the power plants. In Bangladesh, all power plants installed by government is considered as key point installation for ensuring top most security related to it. Power plays an important role for the development of a country like Bangladesh who is trying the best for developing socio-economic condition.

However. in recent past, it was the critical time for Bangladesh when the question of electrical power comes in front. Power crisis had hiked at the peak. Day by day it was becoming impossible for the Government of Bangladesh (GOB) alone to supply power for all. Hence, GOB approved and encourage Independent Power Producer to install and operate their own plant as well as took strategic decision of having Quick-Rental and Rental Power Plants to meet the basic power demand in short term as well as to meet peak demand in the long run. It leads the government huge investment to ensure sustainable growth of power generation. More than 38,000 MW of generation capacity has suggested for construction against 33,000 MW forecasted power demand by the year 2030. As planned, approximately 10% of the total generation will be produced by Combined Cycle Power Plant (CCPP). [1]

1.2 BEHIND THIS WORK

Quality, cost and time is three factors those could not be optimized simultaneously. That is if anyone tries to optimize any two of the above factors, the others will be compromised. In other word, if cost and quality are optimized time consumption will be highest. Similarly, cost and time could be minimized with sacrificing the quality. Again, high degree of quality in shortest time could be achievable with high cost. However, in power plants where decision making could be a critical issue to handle some emergencies and failure to handle it correctly could lead to loss of properties or equipment damages or even fatal accident, optimizing the three constraints are more difficult. Many situations including near misses, higher startup time, startup-failure, complexity in emergency handling, plant trip, increased plant outage, harm or damage to equipment and minor to severe human injury are common in the industry as a consequence of the failure of operator to follow the standard during their job. To avoid such kind of mistakes and to stay in line as much as possible with the three constraints in a Combined Cycle Power Plant, SOP is deemed to be helpful.

1.3 OBJECTIVES

The main objective of this research work is to develop Standard Operating Procedure (SOP) for a Combined Cycle Power Plant. The Specific Objectives are:

1. To standardize the operational activities of the operators' routine work.
2. To make ease for operator to take decision during operational activities.
3. To reduce the impact of human factors on day to day operation from operator to operator
4. To minimize deviation of compliance to organizational policies, HSE (Health Safety and Environment) and Legal Issues.
5. To increase the degree of competency and the reliability of the operators.

1.4 EXPECTED OUTCOMES AT THE BEGINNING OF THE STUDY

At the beginning of the study following outcomes has been expected

1. Uniformity of Operational Activities from operator to operator
2. Improved Compliance to organizational Policy
3. Improved Compliance to HSE and Legal Issues
4. Reduced trouble in decision making
5. Reduced outage time and Increase Plant Availability Factors in long run.

1.5 SCOPE OF THE THESIS

This research work is a descriptive type work. It involves qualitative analysis rather than quantitative analysis due to its nature. The research work is performed on the department of operation in Khulna 225MW Combined Cycle Power Plant. The main purpose of the thesis is to develop SOP and to find out the effect of SOP on operational activities.

1.6 ORGANIZATION OF THE THESIS

This paper is organized in five chapters as follows

1. **Chapter-1: Introduction-** This chapter includes an introductory description of the study to be carried out and expected outcomes.

2. **Chapter-2, Literature Review:** This chapter focuses on previous work and theory related to the work.
3. **Chapter-3, Methodology:** Description of how this research work has been executed.
4. **Chapter-4, Result and Discussion:** The findings of the study are discussed here.
5. **Chapter-5**: **Conclusion and Recommendation-** Conclusion of the study and recommendation for area of further study is the subject matter of this chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 RELATED LITERATURE

Power Plants are the major source of electrical power. Utility of power plant could be improved with cogeneration where combined heat and power is produced for process application using heat recovery boiler or backpressure turbine. Between two broad categories of cogeneration, namely, Topping cycle and Bottoming cycle, only the topping cycle is cost effective. Example of cogeneration system includes back pressure turbine where steam after power generation is used to heat in paper and chemical industries. A form of cogeneration could be a combine cycle power plant (CCPP); highly efficient technology is used for electricity generation where a steam turbine is operated with the recovered energy from exhaust of a gas turbine (Rankine cycle is combined with Brayton cycle) through Heat Recovery Steam Generator. Combined Cycle could be constructed with and without supplementary fire. It is also possible with Nuclear Power Plants. [2]. The CCPP could be configured in different sizes and types. Combined cycle is also preferred for higher efficiency compared to traditional plant. Obviously, the higher efficiency is achieved by utilizing the waste heat from the first cycle to the second cycle. That is, additional power output is obtained without additional fuel and thus the system becomes economically profitable [3]. Hossain and Zissan [3] also suggested that, in Bangladesh, combined cycle power plant should be preferable for increasing power output as the country is suffering from gas shortages. CCPP requires a lower capital cost per unit and have a greater IRR (Internal Rate of Return) [4]. Typical steam turbine or gas turbine power plants have around 40% efficiency whereas, a Combined Cycle Power Plant efficiency reached up to 57% [5]. As a world record, more than 62% efficiency was recorded for a CCPP in 2016 [6].

When a system is designed in a way that a failure in the system prevents to put it in operation or, if the failure occurs during operation then complete safe condition is maintained inherently and will prevent or minimize any consequential damages to other equipment, life or environment is known as Fail-safe design [7]. Implementation of Fail-Safe design concept in engineering reduces fatal accidents in the field of technology. Despite the huge development of automation technology in the field of power generation, the requirement of human intervention with particular skill is still essential for a safe and reliable operation of the system. Hence, operation of the system is not deemed as free from human error.

“A standard operating procedure, or SOP, is a set of step-by-step instructions compiled by an organization to help workers carry out routine operations. SOPs aim to achieve efficiency, quality output and uniformity of performance, while reducing miscommunication and failure to comply with industry regulations” [8]. In order to avoid error, procedures should have a standard format to ensure uniformity and easy to follow. Moreover, training should include reasons behind the procedure “why to follow” rather than only introducing how or what to follow [9]. Using HEART (Human Error Assessment and Reduction Technique) to study the human factors for a dyeing industry, it was concluded that, the SOP is helpful to reduce human errors [10]. K. Bergerova [11] worked with SOP in construction industry but she did not evaluate its outcome.

Lack of standardization of activities leads to more human error and accident. This could be avoided with a good Standard Operating Procedure (SOP). A SOP could be a starting point of standardization of activities which made the foundation for continuous improvement. The SOP must be suited to the literacy levels of the user, and as part of this, the readability of procedures is important. We could not come across any study related to SOP of Combined Cycle Power Plant (CCPP) Operation in Bangladesh and even in the world literature so far. It could be considered that with SOP a plant will be operated more uniformly with no or less variation from operator to operator. It will reduce the influence of human factors and will play a great role in efficient operation of the plant. It will also be a foundation for continuous improvement.

2.2 QUALITY CONTROL

Quality control is a set of processes intended to ensure that a manufactured product or performance adheres to a defined set of quality criteria or meets the requirements of the client or customer. Quality control is ensured by trained worker or personnel. They set up a yard-stick of their product quality and consistently maintain them. The main purpose of quality control is to establish the perfect quality. Quality control standardize production. It lessens mistakes by specifying production activities. Quality control makes sure that the products are within the specification and requirements. Good quality control attracts more consumer. [12] [13]

Quality control inspectors protect the customer from defective products and the company from damage to its reputation due to inferior manufacturing processes. If the testing process reveals issues with the product, the inspector has the option of fixing the problem himself, returning the product for repairs or tagging the product for rejection. [13]

2.3 TOTAL QUALITY MANAGEMENT (TQM)

Total Quality Management (TQM) is a process that describes a long-term management approach that results customer satisfaction. In TQM process, all department's member of an organization participates in improving process and the working environment they used to work. Basically, this is a system of customer focused management. [14]

The exact origin of the term "Total Quality Management" is not established [15]. The history of quality management can be described all the way back to the Middle Ages. Work completed by journeymen and apprentices were evaluated and inspected by the skilled worker to ensure that quality standards were met in all aspects of the finished product, ensuring satisfaction of the buyer. And while the history of quality management has gone through several changes since that time, the end goal is still the same. It was during the 1920's when quality management systems, started to surface. While the focus of quality management was still on the end product, it was the first time that statistical theory was applied to product quality control. Product quality control was determined through inspections. This involved measuring, examining and testing the products, processes and services against specific requirements to ensure that each element adhered to set standards and guidelines. It was also during the 1940's that Japan caught wind of Total Quality Management. During the first international quality management conference in 1969, Feigenbaum would first use the phrase Total Quality Management. Feigenbaum, however, would not meet the depth of understanding of the term that Japanese attendee and speaker, Ishikawa would. Ishikawa would indicate during the conference that TQM should apply to all employees within the organization. [12] [14] [16]

2.3.1 TQM Principles:

American Society for Quality Control illustrate the basic elements of TQM as follows:

1. Policy, planning and administration
2. Product design and design change control
3. Control of purchased material
4. Production quality control
5. User contact and field performance
6. Corrective action and

7. Employee selection, training and motivation

TQM is a set of core values and principles on which the organization is to operate. As the customer is the ultimate determiner of the level of the product so the basic principle is to improve the quality of the product and reach to the customer. The fundamental part of TQM is a process of thinking how to improve the product quality and employee participation. [12] [14]

2.3.2 Making TQM Work:

As TQM is a continuous process of improvement so it requires participation of every person in the organization whether in management or in the bottom line job. All member of the company including top to bottom should participate in their management activity.

Secondly, achieving small goal or small gain is another key characteristic to make the TQM work. Large gain is accomplished by achieving some small goals in long-term.

Team work is the third and the most important ingredient for total quality management. It helps sharing knowledge, identifying problems, finding opportunities, understanding the solution of the overall process and achieving goals.

TQM is a long-term process and suits Japanese corporate culture than the American. Because American corporate culture is short term. They focus on the quarterly based results whereas Japanese focus on the yearly results. [14]

2.3.3 Practicing TQM:

Though TQM emphasized on quality but this is mainly a philosophy of management. TQM has some effect on gaining customer loyalty. Following this philosophy Japanese abled to gain huge profit. TQM emphasized on discipline and planning also. Deeming and Juran provide the core assumption of total quality management. From those assumption, it can be concluded that an organization needs both quality system and quality culture to achieve the goal. [14]

2.3.4 Basic Tools of TQM

Basic tools of TQM vary from expert to expert. The eight commonly found tools are as follows [12]

1. Check Sheet
2. Stratification Analysis

3. Histogram
4. Process Flow Chart
5. Cause-Effect Diagram
6. Scatter Diagram
7. Pareto Analysis
8. Control Chart

All the tools of the TQM are used to find out the answer to a series of questions known as 5W2H and the purposes is as follows: [12]

1. What? – What to investigate?
2. Why? – Why it is happening?
3. Where? – Where is the source of the defect?
4. When? – When the defects occur? In the system or time dependent?
5. Who? – Who is responsible for this?
6. How much? – How much cost is involved?
7. How? – How to identify and how to eliminate?

2.4 5-S

One of the methods of determining an organizational approach to its business is to evaluate its workplace organization capability and visual management standard. 5S engages people using 'Standards' and 'Discipline'. This is not about housekeeping but about concentrating on maintaining the standards and discipline to manage the organization. It is a systematic and methodical approach allowing teams to organize the workplace in the safest and most efficient manner. The entire process is managed using audit documents shaped by the teams [17]. Step by step process must be followed properly to make 5S to be effective in any organization. Followings are the key to 5S:

2.4.1 Seiri or Sort:

Seiri is a process which make work easier by eliminating obstacles. It reduces chances of being disturbed with unnecessary items and remove all parts or tools that are not in use. It makes sure to clear all working floor except using materials. Action plan for this step are as follows:

1. Identify items not necessary to complete work.
2. Develop criteria for disposal for those items.

3. Red Tag the item and put into red tag area.
4. Classify the items by frequency of use.

2.4.2 Seiton or Set in Order:

Seiton is a process that arranges all necessary items so that they can be easily selected for use. Seiton prevents loss and waste of time by arranging work station in such a way that all equipment can be found easily. It makes sure to maintain safety. Action plan for this step are as follows:

1. Make sure the all unnecessary items are eliminated.
2. Considering of the work flow, decide which things to put where.
3. Plan based on the principles and locate things accordingly.
4. Use 5 whys to decide where each item belongs.
5. Locate needed items so they can be retrieved in 30 to 60 seconds with minimum steps.
6. Make a clear list of items with their locations.
7. Outline locations of equipment, supplies, common areas and safety zones.

2.4.3 Seiso or Shine

Seiso is the process that represents to clean the workplace daily or routine basis to prevents deterioration of machinery and equipment. Action plan for this step are as follows:

1. Adopt cleaning as a daily activity and as a part of inspection. Cleaning the workplace before starting of the job and before closing the job.
2. Find ways to prevent dirt and contamination.
3. Identify and tag every item that causes contamination.
4. Keep a log of all places and areas to be improved.

2.4.4 Seiketsu or Standardize

Standardize the best practices in the working area and always maintaining the high standards in workplace organization. This process makes sure that everything is in the right place. Action plan for this step are as follows:

1. Check that the first three 3’s are implemented properly.
2. All team activity documents lists should be publicly displayed on a 5S board.
3. Standardize cleaning schedules using the 5S owner check sheets.

4. Create a maintenance system for housekeeping. Make a schedule for cleaning of the workplace.
5. Assign responsibility to individuals for a work area and machinery.
6. Instead of criticizing poor cases, praise and commend good practices or good performances.

2.4.5 Shitsuke or Sustain

Shitsuke is goal oriented process. It makes sure that everyone is following the 5s process and the first four process is maintained properly. It is not harmful to harmful. Action plan for this step are as follows:

1. Everyone in the workplace should treat if they would their home.
2. Periodic facility management involvements are required to check that the first four S's are implemented perfectly.
3. Senior management should do a periodic review of the status of 5S.
4. Dedication, devotion and commitment are needed in implementation of 5S on daily basis.
5. Senior management should initiate a celebration for the total process in initiating and carrying forward the program.
6. Root cause problem solving process should be in place where root causes are eliminated and improvement actions include prevention.

5S is a structured process to get a workplace cleaned up, organized, standardized, creating efficiency. It improves efficiency, reduces space that used for storage and improves safety. It makes employee feel better about their work [18]. After complete implementation of 5-S, the system moves to the area of "Kaizen" [12].

2.5 KAIZEN

Kaizen is a Japanese word means 'change for better' or 'continuous improvement' Kaizen refers improvement in productivity in a methodical process. The word refers to any improvement. One time or continuous, large or small. Kaizen is a long-term approach to work systemically to achieve improvement and efficiency. As Kaizen can be applied in any work but it is the best process being used in lean manufacturing. Japanese were the first to use Kaizen method in their business after the second World War. They were partly influenced by American business and their quality managements as the American have the best quality management teacher in the world. Kaizen could be a part of action plan and or a part of philosophy. As an action plan, Kaizen solves the problem and implementation is swift and sure. Kaizen focused on improving some specific area but only within the company. Kaizen does not change employee culture but it has some strong emphasis on plant floor employees. As a philosophy, Kaizen is a strategy where employees at all levels of a company work together protectively to achieve regular work properly. Kaizen is a natural way of thinking for every employee within the company. Kaizen combines collective talents within the company to create a powerful way for improvement. Kaizen is applied as an action plan through a consistent and sustained program of successful kaizen event. It teaches employees to think. The main goal of kaizen is to simplify the job. By having employees, management together, it constantly suggests improvements. By constantly improving processes, bringing new standards Kaizen improve job safety. As kaizen eliminates waste so it can save resources. As improvement can come from any one and any time so the idea of kaizen is helpful to bring new improvements. [12] [19]

Effect of "Kaizen" from Imai [20] has found as illustrated as follows [21] .

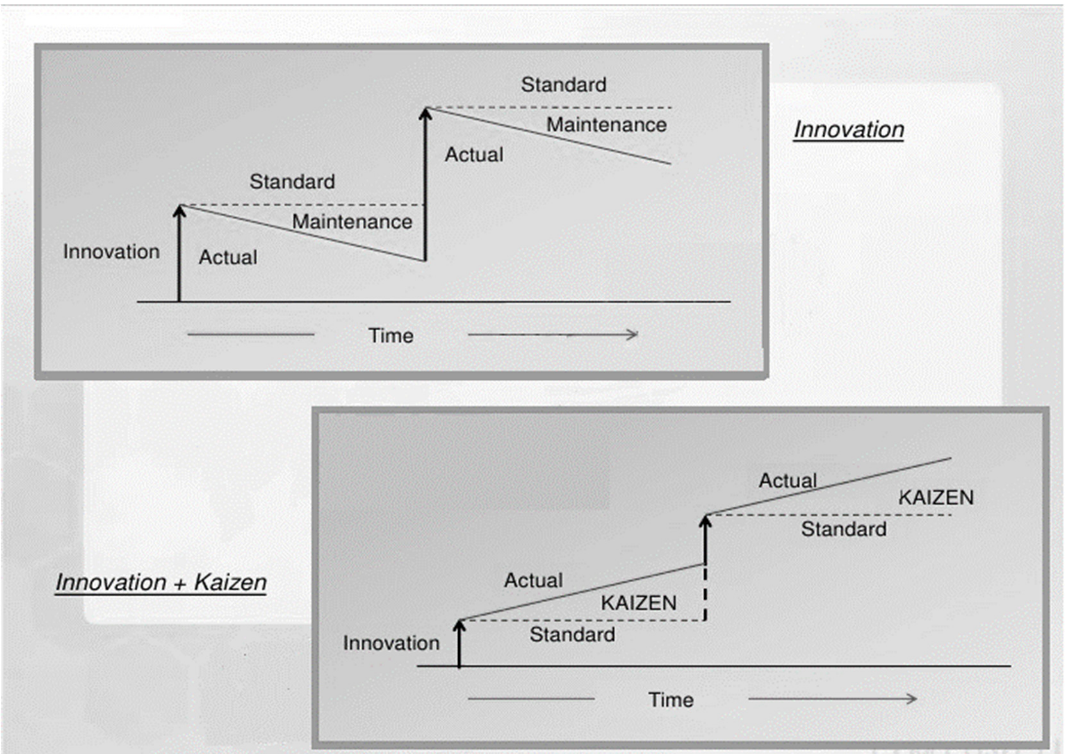

Figure 1: Effect of Kaizen with Innovation

However, new standard achieved with Innovation step could be obtained as a result of

Demings Wheel i.e. Plan-Do-Check-Act (PDCA) activities as illustrated here.

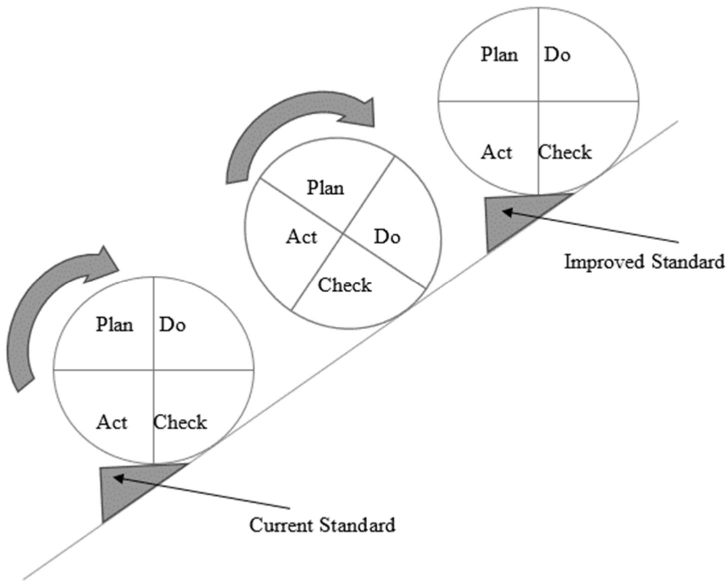

Figure 2: PDCA Cycle could be a good tool to improve standard.

2.6 POINT OF VIEW OF STANDARDIZING

"There can be no improvement where there are no standards" (- Imai) [20]

K. Bergerova [11] pointed out both advantages and disadvantages connected to standardaizing from Brunsson & Jacobsson [22] as follows:

For Standardizing

1. Helpful Instrument for Information Transfer
2. The method for coordination
3. Simplification
4. Best practice
5. Advantage of large scale

Against Standardizing

1. Resemblance
2. Stabilize the world too much
3. Are standards really the best practice?
4. Let the market decide
5. Does standardization mean innovation or codified established practice?

2.7 BIRTH OF THE SOP

Standard Operation Procedure (SOP) were found in history from 1856 and was born to eliminate human error. On 17 July 1856, in United States a head-on collision occurred in between two passenger trains. It leads to burst boilers and the sound was so enormous that it was heard from five miles apart. This incident lead to death of approximately 60 person and injury to a hundred. The incident was known as The Great Train Wreck of 1856. The root cause of the incident was human error [23]. The Great Train Wreck of 1856 initiated a public outcry to implement more standardized safety measures and thus Standard Operating Procedures were born [24].

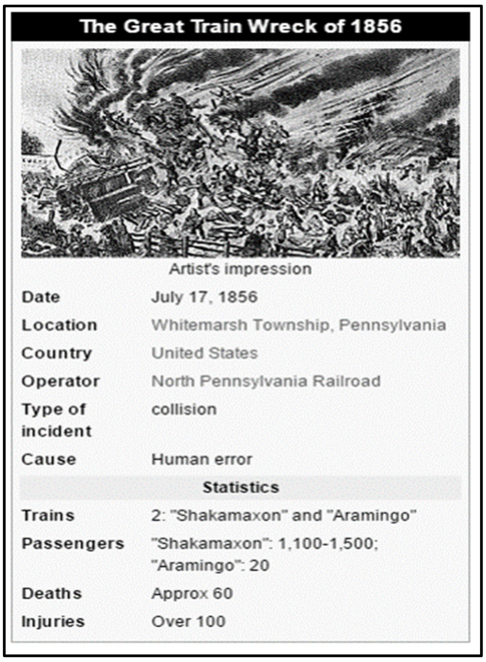

Figure 3: The Great Train Wreck of 1856 - Statistics from Wikipedia

2.8 ISO CERTIFICATION

ISO, the International Organization for Standardization, works for the promotion of global standardization for specifications and requirements for materials, products, procedures, formats, information and quality management. Certification under ISO standards is not a license that permits an activity rather it merely assures that the ISO-required management of processes and documentation is in place to satisfy all the requirements for standardization and quality assurance.

Individual business or organization specify the requirements and operating procedures to satisfy their requirement. Most ISO standards deal with processes or products. However, ISO 9001 and ISO 14001 are generic management system standards applicable to any organization. They are the most common ISO certifications. ISO 9001 and ISO 14001 are a set of requirements for quality-management systems and for environmental-management systems respectively. Neither regulates what is done or should be done by an organization. However, each establishes a framework for effective operation. Certification in either ISO 9001 or ISO 14001 involves a series of internal audits and ISO audits to ensure that all procedural requirements and documentations are followed during every day practices. [25]

CHAPTER 3: METHODOLOGY

3.1 GENERAL:

A study will be done in a systematic manner on some important operational activities of Khulna 225MW Combined Cycle Power Plant CCPP of North-West Power Generation Company Limited (NWPGCL) in Khulna, Bangladesh. In this descriptive type of study, we tried to identify the outcome of SOP in a CCPP. All the operation engineers will be requested for participating in the survey, group discussions and training program on SOP.

3.2 PROCEDURE

Methodology or procedure in conducting a research is always a major concern. A careful and sincere consideration is very important to design the research methodology. For this research work a qualitative study will be carried out rather than the quantitative method due to its nature and application. Utmost care has been taken in all aspect of this study to ensure collecting reliable information for analyzing in this study. This study was purely related to the operational activity. As such, the scope of the study is kept limited in Operation Department of the Plant. All the engineers who is working directly in operation department of the power plant will be selected as target group of the study. To accomplish the objectives of the study, followings steps will be carried out:

3.2.1 Step-1: Observation

To understand the whole process and to get a clear insight of the total operation process and procedure as practiced in the power plant, close observation will be made through active participation and group discussion with the operation team of that power plant. With the observation and discussion, initially some job will be selected for developing SOP for those jobs. A questionnaire will be developed to get the operators' viewpoints on the job regarding degree of complexity, involvement of decision making, issues regarding compliance of safety quality etc. for the selected job.

3.2.2 Step-2: Development of Draft SOP

A detail analysis for the selected jobs will be carried out to identify how works are executed at present. Requirements to comply organizational policies, HSE (Health Safety and Environment) and Legal Issues (if any) will also be identified in this step. The requirement of SOP also will be pointed out during this phase. The detail study of the plant layout, Operation and Maintenance Manual from OEM, Manufacturers' recommendation, Plant Piping and Instrumentation Diagrams (P&ID) will be conducted in this step. In addition, by discussing with the Operation Team, the gaps between O&M Manuals general guidelines and the present operational difficulties will be identified. Based on the knowledge acquired in this step initially a Draft or Provisional SOP will be developed for each select job. Finally, Draft SOP will be released for test purpose.

3.2.3 Step-3: Testing of Draft SOP and Development of Final SOP

After having the Draft SOP, it is important to test and verify its accuracy in real operation to identify any requirements for improvement. After testing, Final SOP will be developed and released with necessary modification, correction or required improvement.

3.2.4 Step-4: Study the effect of SOP

Operators will be trained on the SOP and how to use it. Afterwards, with a survey, the effectiveness of the SOP will be evaluated on various objectives.

The whole process of study work can be shortly explained by with Figure No 4

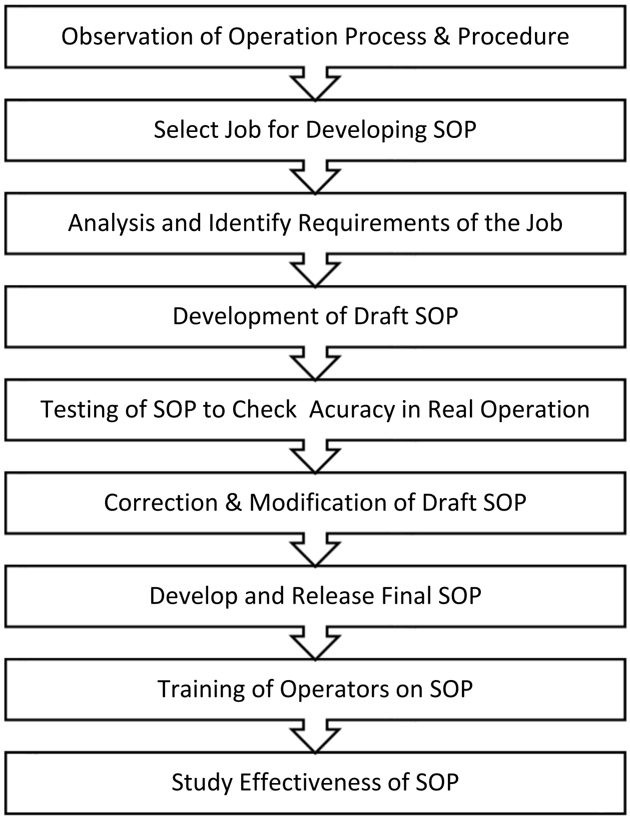

Figure 4: Procedure of the Study

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CHAPTER 4: RESULTS AND DISCUSSION

4.1 PROCESS INFORMATION

4.1.1 Khulna 225MW CCPP

North-West Power Generation Company Limited (NWPGCL) was formed with a view to meeting the growing demand of electricity in the North-West region of the country. This company was incorporated and registered in August 2007 under the framework of the Government Power Sector Reforms Policy and the provision of the Companies Act, 1994. The Company has primarily started its functioning with Khulna 150 MW Peaking Power Plant Project, Sirajganj 150 MW Peaking Power Plant Project and Bheramara 360 MW Combined Cycle Power Development Project. After the commercial operation date of Khulna 150 MW Peaking Power Plant, the authority intended to upgrade the plant to 225MW CCPP under another development project.

4.1.2 Organogram of Khulna 225MW CCPP

Khulna 225MW CCPP is continuing its operation headed by the Plant Manager having the rank of Chief Engineer. To take care of the technical issues the Superintending Engineer is responsible on behalf of Plant Manager. Basically, four technical division were functioning to achieve the Operation and Maintenance related requirement of the plant. These four division are namely Operation, Mechanical Maintenance, Electrical Maintenance and Instrumentation & Control. The Head of each division is in the rank of Executive Engineer. According to the need of each division different technical manpower has been deployed to achieve functionality of respective division.

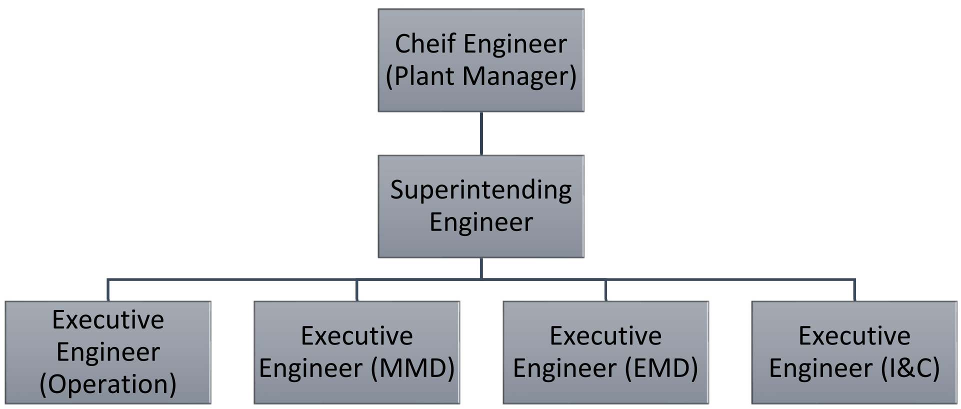


Figure 5: Organogram indicating Major Technical Divisions in Khulna 225MW CCPP

4.1.3 Operation Division

Executive Engineer (Operation) is responsible for leading the operation division to achieve its goal and to satisfy the customer need. Operational activities are carried out in three shifts namely A, B and C round the clock by four groups of identical setup. Three groups carry out their duty while another group enjoy their off-days. The nature off the duty is rotating shift.

Each group is leaded by a Shift Charge Engineer in the rank of Sub-Divisional Engineer (SDE). Two (2) Assistant Engineers and two (2) Sub-Assistant Engineer are the helping hands to perform the control room and field operation during their duties. One (1) Technical Helper is also in the group to assist field operation. Operation team is responsible for plant startup, plant shutdown, monitoring during normal operation, issuing of PTW (Permit to Work) and ensure safety during maintenance activity following LOTO (Lock Out Tag Out) procedures, planning for upcoming shutdowns and startup, operation cost optimization etc. Ensuring safety is maintained with utmost importance by the operation division.

4.1.4 Present Operation Process

At the initial stage of this study operation of this power plant was found being carried out on experience basis. That is the operators were working merely on the basis of past experience though their experienced knowledge were not properly documented and address in a systematic manner. Thus, the senior operators played a great role on decision making during plant startup or shutdown or even on normal operations.

On the contrary, this organization and the plant are ISO 9001, 14001 and OHSAS certified. ISO 9001 required SOPs as its requirement. On investigation, it was found that the operators of this power plant were using O&M (Operation and Maintenance) Manual as SOPs. This became more difficult to use when the question of a specific task came due to the huge information and volume of such a manual. For example, when operators were asked to start the GT then they use the GT Operating Instruction [26]. Again, the same manual was used as SOP for GT Shutdown or for Normal Operation. There was no question that the operator must study the O&M manual for their professional proficiencies and competencies. However, using O&M manual as SOP could rather more difficult and inappropriate. In addition, this manual has about 142 pages and makes more difficult to find appropriate information for a specific job. On the other hand, for example, a SOP with no more than 6 pages could contain all the necessary and specific information systematically and sequentially for safe and reliable startup of GT. Moreover, the manuals are generic rather than specific. Thus, many operational steps required to be modified for the said power plant. For example, the plant was built as OCGT (Open Cycle Gas Turbine) by one EPC contractor and then modified as CCPP (Combined Cycle Power Plant) by another EPC contractor. Thus, many information of old documents is not valid in current situation.

4.2 DEVELOPMENT OF SOP

At first, we tried to understand the whole process through participation with the operation team of the power plant and got a clear insight regarding their works. This participatory investigation was carried out from October 2016 to November 2016. Almost in every step numbers of group discussion were held with the operators to cross-check information, establish effective communication, to be clarified and to avoid confusion.

Participatory involvement in to the entire operational system helps us to identify some region where we could work for improvement through SOP. For developing SOP for selected routine works, we go through the Operation Manual provided by the Original Equipment Manufacturer (OEM) and the EPC (Engineering Procurement & Construction) Contractors recommendations. In addition, by discussing with the Operation Team, we tried to identify the gaps between O&M Manuals general guidelines and the present operational difficulties. The relative issues required to be address in SOP have been identified and arranged in a systematic and sequential manner to produce the initial Draft SOP. We tried to address all operational issues and to make the SOP precise for operational ease. Draft SOP was prepared during November 2016 till February 2017.

Due to low demand from NLDC (National Load Dispatch Center) in winter the plant was kept shutdown from the last week of November 2016 until 1st day of February 2017. During and after the plant startup, Draft SOP were tested to check its accuracy and suitability in real operation. This SOP was corrected according to the findings during test phase. Testing, correcting and finalizing SOP were carried out from February 2017 to April 2017. In Parallel, an online survey (vide Appendix-A for the Questionnaire) was also conducted with a set of questions developed to acquire the comprehensive nature of the selected operational activities from the operators' viewpoints. The final and tested version of SOPs were made available for the operators. Operators are trained on the SOP in April 2017. Afterwards, with another online survey (vide Appendix-B for the Questionnaire), the influence of the SOPs was studied in May 2017. The final and tested version of SOPs are as follows:

4.2.1 SOP for Startup of Gas Turbine

A. Job Name	**Startup of Gas Turbine**	
B. Definitions	BOP	Balance of Plant
	CCPP	Combined Cycle Power Plant
	CI	Combustion Inspection
	EDG	Emergency Diesel Generator
	FG	Function Group
	GCB	Generator Circuit Breaker
	GT	Gas Turbine
	HGPI	Hot Gas Path Inspection
	HMI	Human-Machine Interface
	HRSG	Heat Recovery Steam Generator
	I/A	Instrument Air
	JOP	Jacking Oil Pump
	MCL	Maximum Continuous Load
	NLDC	National Load Dispatch Center
	OCGT	Open Cycle Gas Turbine
	OLTC	On Load Tap Changer
	SFC	Static Frequency Convertor
	SSD	Static Starting Device
	TAT	Temperature After Turbine
C. Scope	Applicable only for Startup Operation of Gas Turbine with High Speed Diesel (HSD) fuel of Khulna 225MW CCPP of NWPGCL.	
D. Safety Instructions	**1.** Confirm BOP firefighting equipment are available and ready for operation. **2.** Access restrictions and communications are in place. **3.** GT CO_2 Firefighting system is active and in automatic mode. **4.** GT protection system shall be enabled. **5.** No personnel are inside or nearby GT enclosure. **6.** Ensure all active PTWs are closed and any Isolation done is normalized. If not, then individually address each active PTW and Isolation whether it has any issue [obvious or latent] with the job- **Startup of Gas Turbine**. If yes, Stop the process and close that PTW. Start-over the process- **Startup of Gas Turbine**. **7.** Ensure that upcoming start-up of GT is informed to all involved personnel. **8.** GT EDG is ready to start	

E. Compliance	**1.** Policy: Communicate with NLDC for Startup Permission. **2.** Health: Use Standard PPE during Field-operation. **3.** Environment: NOx and SOx Emissions must be under limit.
F. Known Hazards	**1.** Hazard of suffocation inside GT Enclosure. **2.** Rotating Parts **3.** Explosive atmosphere **4.** Flammable Liquids **5.** High Noise
G. Competencies	All personnel involved with the job must be familiar with the system and process as well as properly trained for the job - **Startup of Gas Turbine**
H. Responsibilities	Shift Charge Engineer will be solely responsible for entire operational process
I. Man Power	**1.** Competent Shift Charge Engineer – for coordination – 01 **2.** Competent Assistant Engineer – for control room operation – 01 **3.** Competent Sub Assistant Engineer – for field operation – 01
J. No of Steps	33 Operation Steps
K. Description of Operation Steps to be followed	

STEP NO.	Pre-criteria (if any)	Action	Remarks (if any)
1.		Confirm that Safety Instructions [Clause-C] is complied.	
2.		Confirm that Rotor Barring System was in operation actively for at least continuous six (6) hours from rotor standstill condition.	
3.		Ensure that GT walk down procedure has carried-out [if any Maintenance Inspection (CI or HGPI) has performed]	
4.	**Not OCGT**	Open HRSG Stack Damper.	**Skip if OCGT**

STEP NO.	Pre-criteria (if any)	Action	Remarks (if any)
5.		Ensure both GT Instrument Air Compressors are healthy and in operation with sufficient I/A pressure.	
6.		Connect BOP I/A with GT I/A. [if GT I/A Compressor is not healthy]	
7.		Ensure Soft reset of SSD is performed	
8.		Diverter System has no Alarm and diverter accumulator pressure is healthy.	**Skip if OCGT**
9.	**Not OCGT**	Ensure CCPP criteria for diverter and HRSG are satisfied in GT HMI	**Skip if OCGT**
10.		Check 6.6 KV Bus Voltage and if required adjust by OLTC	
11.		Ensure HSD is selected as Fuel in GT HMI	
12.		Ensure Low Omega is active	
13.		All field equipment and protection systems are in normal state and with no alarm	
14.	**Not OCGT**	Boiler drum level is in limit and Ignition Release criteria is satisfied in GT HMI.	**Skip if OCGT**
15.		Check and confirm that GT start release criteria is satisfied in GT HMI.	
16.		Ensure no other discrepancies in BOP HMI.	
17.		Ensure no other discrepancies in GT HMI.	
18.		Initiate the GT start-up sequencer command GT HMI	
19.		Follow actively the On-Screen Instruction in GT HMI	

STEP NO.	Pre-criteria (if any)	Action	Remarks (if any)
20.		Ensure the followings: i. FG – LOIL (Lube Oil System) is active ii. Fuel oil & NOx water forwarding pumps are running in BOP HMI iii. Fuel & NOX water injection pumps are running in GT HMI iv. FG- Power oil is active v. Hydraulic safety test successfully carried out by the system. vi. All Blow-off valves are open vii. Test accumulator purge finished.	
21.		At Step –no 83 SSD will be started and By-pass Stack purging will be started at 834 rpm	
22.	**Not OCGT**	As soon as By-pass stack purging completed and "GT REQUEST OPEN DAMPER" in CCPP HMI is active, open the diverter damper fully.	**Skip if OCGT**
23.	**Not OCGT**	HRSG and Main Stack Purging will be performed	**Skip if OCGT**
24.		After all purging completed GT speed will decrease and afterward speed will increase for ignition.	
25.		Open FOIL (Fuel Oil) Page in GT HMI and observe ignition torch and flame status (Flame established at 925 to 975 rpm)	
26.	**Not OCGT**	Close the diverter damper completely as soon as GT speed reached 1200 rpm.	**Skip if OCGT**

STEP NO.	Pre-criteria (if any)	Action	Remarks (if any)
27.		Closely follow-up i. Shaft Vibration in Critical Speeds [@ 1050-1250 & 2100-2300 rpm] ii. TAT temperature and TAT Spread iii. SFC stopped at 2700 rpm. iv. JOP stopped at 2700 rpm. v. Stage-1 Blow off valves closed 2700 rpm vi. Stage-3 Blow off valves closed 2820 rpm vii. Excitation FG on at 2880 rpm viii. If desired select IDLE MODE operation. ix. Request NLDC for necessary frequency control x. Synchronization FG on. xi. GCB will be closed when synchronization completed. xii. Synchronization FG off. xiii. All Blow off valves closed xiv. Generator on grid	
28.		Enter 10MW as Load Set Point	
29.		Adjust generator terminal voltage as required.	
30.		Carry out field inspection	
31.		If High Omega is desired, deactivate Low-Omega before Base Load reached and at more than 50% load.	
32.		If desired select MCL after Base Load Reached	
33.		Disconnect BOP I/A with GT I/A. [if connected]	
END OF SOP			

4.2.2 SOP for Startup of Heat Recovery Steam Generator

A. Job Name	**Startup of Heat Recovery Steam Generator**	
B. Definitions	BOP	Balance of Plant
	CCPP	Combined Cycle Power Plant
	EDG	Emergency Diesel Generator
	FG	Function Group
	FWP	Feed Water Pump
	GCB	Generator Circuit Breaker
	GT	Gas Turbine
	HMI	Human-Machine Interface
	HP	High Pressure
	HRSG	Heat Recovery Steam Generator
	I/A	Instrument Air
	IP	Intermediate Pressure
	LP	Low Pressure
	MOV	Motor Operated Valve
	NLDC	National Load Dispatch Center
	ST	Steam Turbine
	TAT	Temperature After Turbine
	WTP	Water Treatment Plant
C. Scope	Applicable only for Startup Operation of HRSG of Khulna 225MW CCPP of NWPGCL.	
D. Safety Instructions	**1.** Access restrictions and communications are in place. **2.** No unauthorized personnel are nearby HRSG / ST Area. **3.** Ensure all active PTWs are closed and any Isolation done is normalized. If not, then individually address each active PTW and Isolation whether it has any issue [obvious or latent] with the job - **Startup of Heat Recovery Steam Generator**. If yes, Stop the process and close that PTW. Start-over the process **Startup of Heat Recovery Steam Generator**. **4.** Ensure that upcoming start-up of HRSG is informed to all involved personnel. **5.** Ensure that all protection in control system is active and in auto-mode and there is no intervention in the protection system. **6.** Boiler Protection System is active and functioning. **7.** Firefighting systems are standby and ready to operate **8.** Both EDG is ready to start and in auto mode.	

<table>
<tr><td>E. Compliance</td><td>1. Policy: Communicate with NLDC for Startup Permission.
2. Health: Use Standard PPE during Field-operation.
3. Environment: NOx and SOx Emissions must be under limit.</td></tr>
<tr><td>F. Known Hazards</td><td>1. High Temperature and High Pressure Steam
2. Use of Chemicals</td></tr>
<tr><td>G. Competencies</td><td>1. The operator of power plant must be familiar with operation regulation, and ensure that operator controls the running parameters of system control devices what should not exceed the design settings.
2. All personnel involved with the job must be familiar with the system and process as well as properly trained for the job - Startup of Heat Recovery Steam Generator.</td></tr>
<tr><td>H. Responsibilities</td><td>Shift Charge Engineer will be solely responsible for entire operational process</td></tr>
<tr><td>I. Man Power</td><td>1. Competent Shift Charge Engineer – for coordination – 01
2. Competent Assistant Engineer – for control room operation – 02
3. Competent Sub Assistant Engineer – for field operation – 02
4. Competent Junior Assistant Manager (Chemical) – 01
5. Competent Work Assistant – for field work – 02</td></tr>
<tr><td>J. No of Steps</td><td>46 Operation Steps</td></tr>
<tr><td>K. Important Information to be complied</td><td>1. Startup of HRSG is a slow and complex process. Don’t hurry and have patience. Try to comply all criteria and never allow action /condition not conforming acceptable criteria to save time.
2. Drum Level Limit
<table>
<tr><th></th><th>HHH</th><th>HH</th><th>LLL</th><th>LL</th></tr>
<tr><td>HP</td><td>≥ +203</td><td>≥ +153</td><td>≤ -694</td><td>≤ -203</td></tr>
<tr><td>IP</td><td>≥ +203</td><td>≥ +153</td><td>≤ -445</td><td>≤ -203</td></tr>
<tr><td>LP</td><td>≥ +203</td><td>≥ +153</td><td>≤ -165</td><td>≤ -203</td></tr>
</table></td></tr>
</table>

	3. Ensure: a. Temperature Gradient of HP part < 4.4 °C/min. b. Temperature Gradient of IP part < 9.3 °C/min c. Temperature Gradient of LP part < 27.8 °C/min **4.** Maximum Allowable Design Pressure a. HP < 9.41 Mpa b. IP < 4.34 Mpa c. LP < 0 .83 Mpa **5.** Ensure a. GT Exhaust Pressure (Static) < 5.88 Kpa b. Chimney Pressure (Static) < 1.27 Kpa
L. Control Philosophy	**1.** Water level of the drum: a. Reduce by Opening Blowdown / Emergency Blowdown b. Increase Water Level by opening Control Valve. **2.** Control Pressure Rising by Limiting Heat Input **3.** Control heat input by limiting GT Load and TAT. **4.** During HRSG Startup, when low pressure system is not healthy with sufficient steam, auxiliary steam should be applied to regulate and control.
M. Description of Operation Steps to be followed	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
1.		Confirm with ST Operator about the Startup of HRSG. Startup of HRSG and ST should be simultaneous.	
2.		Ensure Guillotine Gate is open and Guillotine Cover is closed	
3.		Ensure Diverter System Field inspection is carried out.	
4.		HRSG stack damper is fully open.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
5.		Ensure GT is running in CCPP mode and HRSG Purging is completed.	
6.		Ensure Diverter System is healthy and ON/Active in HMI	
7.		Demi-Water Tank Level is more than 70% and WTP is ready for production.	
8.		Confirm functions of LP, IP, HP emergency water discharging motor-driven valves have no alarm / limitations / blocks and all are operable.	
9.		Lube Oil System of feed water pump is running	
10.		Start any FWP and put the other into standby interlock.	
11.		Reset the first trip condition of boiler to normal position.	
12.		Ensure that No trip is active in HRSG Trip HMI mimic. And Reset all Trips.	
13.		Ensure water level as follows (Starting Water Level): i. HP drums: -50 to -100 mm ii. IP drums: -50 to -100 mm iii. LP drums: -50 to -100 mm iv. Condenser: < 700 mm	
14.		All BOP valves are in proper positions. No Drains and Vents with MOV are manually blocked.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
15.		Ensure Cooling System and By-Pass system is active. i. Vacuum Pump is Running ii. At least one Condenser pump is in operation iii. At least one Cooling Tower Fan is in Operation iv. Condensate System is Ready v. Bypass Steam Valves are Available for operation.	
16.		Ensure that all redundant auxiliaries are in Auto Mode and Ready to start when required. No alarm persists with redundant auxiliaries to prevent its auto start.	
17.		Ensure that I/A is Available for CCPP	
18.		Inform Chemical Personnel about the startup and to monitor and control following dosing according to actual field requirement i. Hydrazine dosing ii. Phosphate dosing for HP, IP, LP	
19.		Reduce GT load to ensure TAT < 370 °C.	
20.		Open Diverter Damper	
21.		Monitor and control the water level of HP, IP, LP drums.	**Until End of SOP**
22.		Ensure temperature difference between upper wall and lower wall of HP and IP drum is less than 45°C	**Critical & Until End of SOP**

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
23.		Open the drain water motor-driven valves on the pipeline of HP, IP, LP super-heater until pressures super-heaters reaches as follows i. HP : 0.07 MPa ii. IP : 0.07 MPa iii. LP : 0.035 MPa	**Until Action is Satisfied**
24.		Ensure that Working pressure ≤ design pressure.	**Until End of SOP**
25.		If this is first time start-up after overhaul, or a long shutdown, Inspect the hanger and support condition of boiler hanger one by one during temperature rising and pressure rising, and ensure the hanger and support remains evenly at hot state	
26.		Monitor pressure of HP, IP, LP drums and saturated temperature until Continuous Superheated Steam is produced.	**Until Action Point (Left Column) is Satisfied**
27.	**For Cold Startup only**	Startup air vent valves must be fully open when GT is igniting, and then close it when temperature gradient reaches to specified value;	**Until Action Point (Left Column) is Satisfied**
28.		Keep startup air vent valves at least 10% opened during all Startup.	
29.		Before increasing GT load for TAT > 370 ^{0}C, Ensure Reheat System has Steam Passing enough for Cooling	**Critical**
30.		Increase GT Load slowly to satisfy allowable Temperature and Pressure Gradient. Coordinate with GT Operator for required load.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
31.		Continuous blow-down can be putted into service according to quality of steam & water in drum of boiler.	**Until End of SOP**
32.		After normal startup, when temperature difference between temperature and saturated steam temperature corresponding to pressure of steam is greater than 27.8 0C close the drain valve of each system.	**Until Action Point (Left Column) is Satisfied**
33.		When pressure rises to 0.1~0.2 Mpa, close the air vent valve at top of boiler drum.	**Until Action Point (Left Column) is Satisfied**
34.	**Ensure Step 29 is Done**	Flush the liquidometer of drum, calibrate the accuracy of liquidometer, flush the guide pipe of pressure gauge and verify the correctness of indication of pressure gauge.	
35.		Inspect expansion condition for expansion joint at inlet flue gas duct, inspect expansion conditions of boiler proper, pipeline, hanger and supporter, and make records. Close the startup air vent valve.	**Repeat Every 60 min until ST at MCL**
36.		Open following valves to ensure all condensate water is drained out i. Outlet drain valve of HP attemperator ii. Drain valve of cold reheat iii. Inlet and outlet drain valve of reheat attemperator	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
37.		When steam output is approximately 25% of Rated load, attemperating water isolation valve can be opened, and when the steam output is lower than this limit, attemperating water isolation valve can be closed	
38.		When HP super heater steam temperature is higher than 400 ºC, Control the outlet temperature of HP super heater steam about 513 ºC with attemperator/ desuperheater.	**Until End of SOP**
39.		When IP super heater steam temperature is higher than 400 ºC, Control the outlet temperature of Reheat Steam about 507 ºC with attemperator/ desuperheater.	**Until End of SOP**
40.		Put HP, IP and LP feed water regulating valve is in auto mode according to the following criteria i. HP steam flow ≥ 130 t/h ii. IP steam flow ≥ 20 t/h iii. LP steam flow ≥ 15 t/h	**Until Action Point (Left Column) is Satisfied**
41.		According to the requirement, decide to open the HP, IP and LP main steam valve and drain valve at some time and conduct the warming for main steam pipeline.	
42.		After Synchronization of steam turbine is done, gradually close bypass valves.	
43.		Pay attention to operation condition of automatic control device.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
44.		Conduct the flushing for each sampling pipeline after startup of boiler, put each instrument of sampling loop into running	
45.		when the steam& water quality not meet the requirements, must conduct the blowdown sufficiently until the steam & water meet the requirements.	
46.		Field inspection	
END OF SOP			

4.2.3 SOP for Startup of Steam Turbine

<table>
<tr><td>A. Job Name</td><td colspan="2">Startup of Steam Turbine</td></tr>
<tr><td rowspan="20">B. Definitions</td><td>BOP</td><td>Balance of Plant</td></tr>
<tr><td>CCPP</td><td>Combined Cycle Power Plant</td></tr>
<tr><td>EDG</td><td>Emergency Diesel Generator</td></tr>
<tr><td>EH</td><td>Electro-Hydraulic</td></tr>
<tr><td>GCB</td><td>Generator Circuit Breaker</td></tr>
<tr><td>GT</td><td>Gas Turbine</td></tr>
<tr><td>HMI</td><td>Human-Machine Interface</td></tr>
<tr><td>HP</td><td>High Pressure</td></tr>
<tr><td>HRSG</td><td>Heat Recovery Steam Generator</td></tr>
<tr><td>I/A</td><td>Instrument Air</td></tr>
<tr><td>IP</td><td>Intermediate Pressure</td></tr>
<tr><td>JAM</td><td>Junior Assistant Manager</td></tr>
<tr><td>JOP</td><td>Jacking Oil Pump</td></tr>
<tr><td>LP</td><td>Low Pressure</td></tr>
<tr><td>MOV</td><td>Motor Operated Valve</td></tr>
<tr><td>NLDC</td><td>National Load Dispatch Center</td></tr>
<tr><td>ST</td><td>Steam Turbine</td></tr>
<tr><td>TAT</td><td>Temperature After Turbine</td></tr>
<tr><td>TG</td><td>Turning Gear</td></tr>
<tr><td>WTP</td><td>Water Treatment Plant</td></tr>
<tr><td>C. Scope</td><td colspan="2">Applicable only for Startup Operation of ST of Khulna 225MW CCPP of NWPGCL.</td></tr>
<tr><td>D. Safety Instructions</td><td colspan="2">1. Access restrictions and communications are in place.
2. No unauthorized personnel are nearby HRSG / ST Area.
3. Ensure all active PTWs are closed and any Isolation done is normalized. If not, then individually address each active PTW and Isolation whether it has any issue [obvious or latent] with the job - Startup of Steam Turbine. If yes, Stop the process and close that PTW. Start-over the process - Startup of Steam Turbine.
4. Ensure that upcoming start-up of ST is informed to all involved personnel.
5. Ensure that all protection in control system is active and in auto-mode and there is no intervention in the protection system.</td></tr>
</table>

	6. ST System is active and functioning. **7.** All Main Protection are Active, Normal and with No Alarm. **8.** Firefighting systems are standby and ready to operate **9.** Both EDG is ready to start and in auto mode.
E. Compliance	**1.** Policy: Communicate with NLDC for Startup Permission. **2.** Health: Use Standard PPE during Field-operation. **3.** Environment: N/A
F. Known Hazards	**1.** High Temperature and High Pressure Steam **2.** Intense Sound
G. Competencies	**1.** All personnel involved with the job must be familiar with the system and process as well as prop0erly trained for the job - **Startup of Steam Turbine**. **2.** Well known to design parameters and control system
H. Responsibilities	Shift Charge Engineer will be solely responsible for entire operational process
I. Man Power	**1.** Competent Shift Charge Engineer – for coordination – 01 **2.** Competent Assistant Engineer – for control room operation – 02 **3.** Competent Sub Assistant Engineer – for field operation – 02 **4.** Competent Junior Assistant Manager (Chemical) – 01 Competent Work Assistant – for field work – 02
J. No of Steps	36 Operation Steps
K. Description of Operation Steps to be followed	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
1.		Startup of ST / CCPP is a slow and complex process. Don't hurry and have patience. Try to comply all criteria and never allow action /condition not conforming acceptable criteria to save time.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
2.		Confirm with HRSG Operator about the Startup of ST. Startup of HRSG and ST should be simultaneous.	
3.		Ensure following systems are active, healthy, has no alarm and in operation. i. ST Lube Oil System ii. EH oil system iii. JOP and TG System iv. auxiliary cooling water v. air compressor vi. circulating cooling water system vii. air cooler of generator	
4.		All BOP valves are in proper positions. No MOV are manually blocked.	
5.		Ensure that all redundant auxiliaries are in Auto Mode and Ready to start when required. No alarm persists with redundant auxiliaries to prevent its auto start.	
6.		Ensure auxiliary power system is normal.	
7.		JOP Pressure is Normal	
8.		Ensure that TG is in continuous operation for at least 04 hours and not less than 2 hours in any case. In case of Hot Start, ensure TG was not stopped after ST shutdown (i.e., Rotor was not in standstill condition).	
9.		Ensure eccentricity of rotor is in allowable range. Record the eccentricity of rotor. Difference of eccentricity between actual value and original value of rotor should not exceed 0.03mm	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
10.		Perform cold flushing by using demi water (with ammonia and hydrazine, PH 8.8-9.3). Flush the LP and HP feed water pipe line.	
11.		Start both vacuum pump to create Vacuum Pressure in Condenser. Keep one Vacuum Pump Standby when Pressure is ≤ -90 KPa.	
12.		Put Shaft-Seal Steam in operation with temperature within 150-260 ^{o}C.	
13.		Generator Cooler Circulating Water is in Operation	
14.		Ask JAM (Chemical) and Ensure that Steam meets the required quality to permit into ST for rolling.	
15.		Stop Turning Gear (TG)	
16.	**TG Stopped**	Initiate LATCH command in DEH mimic to start rolling.	
17.		Ensure and Monitor the followings i. Axial displacement within -0.9 to 0.9 mm. ii. Differential expansion within -2.5 to 5.3 mm. iii. Vacuum of exhaust device is > -85 KPa. iv. Lube oil temperature within 35 to 45 0C, and oil pressure within 0.096 to 0.124 MPa. v. EH oil temperature within 43 to 54 0C, and oil pressure within 13.5 to 14.5 MPa. vi. Main steam pressure within 02 to 3.5 MPa and temperature about 300 0C. vii. Reheat steam pressure within 0.3 to 0.8 MPa.	**Until End of SOP**
18.		Set Target Speed to 600 rpm Speed Gradient 100 rpm.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
19.	**ST at 600 RPM**	Check all parameters and ensure that everything is Normal.	
20.		Set Target Speed to 1800 rpm Speed Gradient 100 rpm.	
21.	**ST at 800 RPM**	Ensure JOP is stopped.	
22.		Check that Speed Gradient is automatically increased to 500 rpm during Critical Speed Range (at 1400 to 1600 rpm of Rotor Speed). Ensure that parameters in TSI mimic are normal.	
23.	**ST at 1800 RPM**	Check all parameters and ensure that everything is Normal.	
24.		Conduct the intermediate speed warmi0ng for unit 30 to 60 min	**Colder the Startup Temperature , Higher the Time**
25.		Set the target of rotating speed as 2940 rpm and make sure rising speed rate is as follows i. Cold Start : 100 rpm ii. Warm Start : 200 rmp iii. Hot Start : 200-300 rpm	
26.		Monitor the parameters of TSI mimic.	**Until End of SOP**
27.		Set the target of rotating speed as 3000 rpm and make sure rising speed rate 50 rpm. Check all the instruments and parameters.	
28.		Stop AC lube oil pump, HP startup pump, and pay attention to the oil pressure.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
29.		Before synchronization, pressure of cold reheat is controlled lower than 0.8 MPa as lower as possible.	
30.		Conduct the synchronizing operation.	
31.		Increase Load slowly until IV is fully opened.	**IV -Valve ID in HMI**
32.		When IV Valve is opened completely i. Put Bypass Control Out ii. Put Megawatt Control In	
33.		Set the target load for ST.	
34.		According to the pressure and temperature of HP Steam of HRSG	
35.		At 40% rated load, if ID Condition is fulfilled, put ID Control In.	**ID -Valve ID in HMI**
36.		Field inspection	
END OF SOP			

4.2.4 SOP for Shutdown of Steam Turbine

A. Job Name	**Shutdown of Steam Turbine**	
B. Definitions	BOP	Balance of Plant
	CCPP	Combined Cycle Power Plant
	EDG	Emergency Diesel Generator
	EH	Electro-Hydraulic
	GCB	Generator Circuit Breaker
	GT	Gas Turbine
	HMI	Human-Machine Interface
	HP	High Pressure
	HRSG	Heat Recovery Steam Generator
	I/A	Instrument Air
	IP	Intermediate Pressure
	JOP	Jacking Oil Pump
	LP	Low Pressure
	MOV	Motor Operated Valve
	NLDC	National Load Dispatch Center
	ST	Steam Turbine
	TAT	Temperature After Turbine
	TG	Turning Gear
	WTP	Water Treatment Plant
C. Scope	Applicable only for Startup Operation of ST of Khulna 225MW CCPP of NWPGCL.	
D. Safety Instructions	**1.** Access restrictions and communications are in place. **2.** No unauthorized personnel are nearby HRSG / ST Area. **3.** Ensure that all protection in control system is active and in auto-mode and there is no intervention in the protection system. **4.** ST Protection System is active and functioning. **5.** Firefighting systems are standby and ready to operate **6.** Both EDG is ready to start and in auto mode.	
E. Compliance	**1.** Policy: Communicate with NLDC for Startup Permission. **2.** Health: Use Standard PPE during Field-operation. **3.** Environment: N/A	
F. Known Hazards	**1.** High Temperature and High Pressure Steam **2.** Intense Sound	

G. Competencies	**1.** All personnel involved with the job must be familiar with the system and process as well as properly trained for the job - **Shutdown of Steam Turbine.** **2.** Well known to design parameters and control system
H. Responsibilities	Shift Charge Engineer will be solely responsible for entire operational process
I. Man Power	**1.** Competent Shift Charge Engineer – for coordination – 01 **2.** Competent Assistant Engineer – for control room operation – 01 **3.** Competent Sub Assistant Engineer – for field operation – 01 **4.** Competent Work Assistant – for field work – 01
J. No of Steps	21 Operation Steps
K. Important Information to be complied	**1.** Allowable Gradient for ST Load reduction < 3 MW/min. **2.** Allowable Gradient for Main steam and Reheat Steam temperature reduction 1 to 2 ^{0}C/min. **3.** Allowable Gradient for Steam Turbine Metal Wall Temperature reduction 1-1.5 ^{0}C/min. **4.** Ensure that the degree of superheat of the steam is not less than 56 ^{0}C **5.** Ensure cylinder temperature during shutdown > 330 – 350 ^{0}C. **6.** The differential temperature between upper and lower cylinder of HP and IP cylinder of steam turbine < 42°C **7.** If during shutdown, temperature of main steam and reheat steam is dropped 50°C within 10 min, Stop the unit immediately. **8.** **IN CASE OF EMERGENCY (ST tripped / stopped during Shutdown:** a. Ensure Generator Breaker is Opened by Reverse Power protection. b. Ensure that HRSG is tripped c. Ensure that Diverter Damper is closed. d. All Main Steam Valves and Regulating valves are Closed.

	e. HP exhaust check valve is closed, f. HP ventilation valve is opened g. Start AC lube oil pump h. Ensure Turning Gear is on i. Go to Operation Step-7 and of this SOP follow the applicable appropriate step according to the actual condition j. If Blackout follow SOP for Emergency Black Out and Trip Handling.

L. Description of Operation Steps to be followed

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
1.		Confirm with HRSG Operator about the Shutdown of ST.	
2.		Perform and Ensure the followings i. Interlock test of AC lube oil pump, ii. DC lube oil pump and HP startup oil pump is normal. iii. Conduct the trail running of JOP, afterward stop and keep JOP standby **iv.** TG is Standby and ready to start	
3.		Ensure that all redundant auxiliaries are in Auto Mode and Ready to start when required. No alarm persists with redundant auxiliaries to prevent its auto start.	
4.		Ensure auxiliary power system is normal.	
5.		Ensure that all redundant auxiliaries are in Auto Mode and Ready to start when required. No alarm persists with redundant auxiliaries to prevent its auto start.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
6.		Ensure auxiliary power system is normal.	
7.		Decrease GT load slowly	**Comply Clause K**
8.	**ST at 40MW**	Attentive for switching of steam source for shaft seal timely, ensure the pressure and temperature of shaft seal.	
9.	**ST at 30MW**	Gradually put LP in bypass operation.	
10.	**ST at 24MW**	Put HP and IP in bypass according to the condition.	
11.	**ST at 16MW**	Ensure that drain water pneumatic valve (HP/IP) of steam turbine is functioning properly. Else Manually Open LP drain water and control according to actual field condition.	
12.	**ST at 12MW**	Ensure that LP cylinder spraying water is opened automatically. Else Manually open, and pay attention to the pressure of condensate water.	
13.	**ST at 10MW**	i. Conduct inspection and ensure all parameters are in within normal range ii. Start AC lube oil pump and startup oil pump iii. Initiate “Latch Off” Command [In case Latch Off not working, Press ST TRIP button at CCR] iv. Ensure Generator Breaker is Opened by Reverse Power protection. v. Ensure that HRSG is tripped	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
		vi. Ensure that Diverter Damper is closed.	
14.	**After Latch off is done**	Ensure that i. All Main Steam Valves and Regulating valves are Closed. ii. HP exhaust check valve is closed, iii. HP ventilation valve is opened iv. Record idling time.	
15.	**ST at 650 RPM**	i. Ensure JOP is started automatically. ii. Start JOP manually [Skip if started Automatically] iii. Ensure that Jacking Oil Header Pressure and Pressure at each pad are normal. iv. Exhaust temperature is normal. v. Ensure that LP cylinder spraying water Stopped	
16.	**ST at 0 RPM**	i. From TG Control Cabinet, Put TG in automatic position ii. Start the turning gear from DCS, iii. Ensure that turning gear runs normally, iv. Pay attention to the eccentricity of rotor. v. Maintain Lube Oil Temp. 33-38 0C during TG Operation	
17.	**Skip for ST desired shortly or on purpose**	i. Stop the vacuum pump ii. Open the vacuum break valve to break the vacuum iii. Stop the steam supplement for shaft seal at Zero vacuum	
18.		Stop the HP startup oil pump and EH oil pump.	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
19.		Keep Condensate water pump running until i. Exhaust temperature of LP cylinder drops to 50°C and ii. hot steam and hot water not discharge to hot well and iii. Condensate water is not being used by any other system.	**Until Action Point (Left Column) is Satisfied**
20.	**Regulating Stage Temperature <100 ^{0}C**	i. Stop TG and ii. Stop JOP	
21.		Field inspection	
END OF SOP			

4.2.5 SOP for Shutdown of Heat Recovery Steam Generator

A. Job Name	**Shutdown of Heat Recovery Steam Generator**	
B. Definitions	BOP	Balance of Plant
	CCPP	Combined Cycle Power Plant
	EDG	Emergency Diesel Generator
	FG	Function Group
	FWP	Feed Water Pump
	GCB	Generator Circuit Breaker
	GT	Gas Turbine
	HMI	Human-Machine Interface
	HP	High Pressure
	HRSG	Heat Recovery Steam Generator
	I/A	Instrument Air
	IP	Intermediate Pressure
	LP	Low Pressure
	MOV	Motor Operated Valve
	NLDC	National Load Dispatch Center
	ST	Steam Turbine
	TAT	Temperature After Turbine
	WTP	Water Treatment Plant
C. Scope	Applicable only for Startup Operation of HRSG of Khulna 225MW CCPP of NWPGCL.	
D. Safety Instructions	**1.** Access restrictions and communications are in place. **2.** No unauthorized personnel are nearby HRSG / ST Area. **3.** Ensure that upcoming start-up of HRSG is informed to all involved personnel. **4.** Boiler Protection System is active and functioning. **5.** Firefighting systems are standby and ready to operate **6.** Both EDG is ready to start and in auto mode.	
E. Compliance	**1.** Policy: Communicate with NLDC for Startup Permission. **2.** Health: Use Standard PPE during Field-operation. **3.** Environment: NOx and SOx Emissions must be under limit.	
F. Known Hazards	**1.** High Temperature and High Pressure Steam **2.** Use of Chemicals	

G. Competencies	**1.** The operator of power plant must be familiar with operation regulation, and ensure that operator controls the running parameters of system control devices what should not exceed the design settings. **2.** All personnel involved with the job must be familiar with the system and process as well as properly trained for the job - **Shutdown of Heat Recovery Steam Generator**
H. Responsibilities	Shift Charge Engineer will be solely responsible for entire operational process
I. Man Power	**1.** Competent Shift Charge Engineer – for coordination – 01 **2.** Competent Assistant Engineer – for control room operation – 02 **3.** Competent Sub Assistant Engineer – for field operation – 02 **4.** Competent Junior Assistant Manager (Chemical) – 01 **5.** Competent Work Assistant – for field work – 02
J. No of Steps	14 Operation Steps
K. Description of Operation Steps to be followed	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
1.		Confirm with ST and GT Operators about the Startup of HRSG. Startup of HRSG and ST should be simultaneous.	
2.		All BOP valves are in proper positions. No Drains and Vents with MOV are manually blocked.	
3.		Ensure that all redundant auxiliaries are in Auto Mode and Ready to start when required. No alarm persists with redundant auxiliaries to prevent its auto start.	
4.		Ensure that I/A is Available for CCPP	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
5.		Cooperate with ST and GT Operator while reducing ST Load and Maintain the Boiler Drum Water Level during load reduction.	
6.		Observe and Ensure that during ST load reduction, Control Valves of ST are gradually Closing whereas Bypass Valves are gradually Opening	
7.		After ST GCB open ensure that Diverter Damper is in Closed Position (Vertical Position). If Diverter Damper closing is not automatically initiated, Trip Diverter Damper Manually with CCR Trip Button.	
8.		Maintain the water level of drum at maximum visible level but prevent water entering the super heater when the drum is full of water.	
9.		After 03 hours of HRSG shutdown, stop FWP	
10.	**Drum Level < 100 mm**	Start Condensate Pump and FWP to supply water and to maintain the Drum Level.	
11.	**LP economizer temperature <100 ^{0}C,**	Stop the recirculating pump.	
12.		Ensure that each system outlet isolation valve of HRSG, all drain valves and all air vent valves are kept closed to minimize heat loss.	
13.		Field inspection	
END OF SOP			

4.2.6 SOP for Shutdown of Gas Turbine

A. Job Name	**Shutdown of Gas Turbine**	
B. Definitions	BOP	Balance of Plant
	CCPP	Combined Cycle Power Plant
	EDG	Emergency Diesel Generator
	FG	Function Group
	GCB	Generator Circuit Breaker
	GT	Gas Turbine
	HMI	Human-Machine Interface
	HRSG	Heat Recovery Steam Generator
	I/A	Instrument Air
	JOP	Jacking Oil Pump
	MCL	Maximum Continuous Load
	NLDC	National Load Dispatch Center
	OCGT	Open Cycle Gas Turbine
	OLTC	On Load Tap Changer
	SFC	Static Frequency Convertor
	SSD	Static Starting Device
	TAT	Temperature After Turbine
C. Scope	Applicable only for Shutdown Operation of Gas Turbine with HSD fuel of Khulna 225MW CCPP of NWPGCL.	
D. Safety Instructions	**1.** Confirm all firefighting equipment are available and ready for operation. **2.** Access restrictions and communications are in place. **3.** GT Firefighting system is active and in automatic mode. **4.** GT protection system shall be enabled. **5.** No personnel are inside or nearby GT enclosure.	
E. Compliance	**1.** Policy: Communicate with NLDC about Shutdown information. **2.** Health: Use Standard PPE during Field-operation. **3.** Environment: Not Applicable	
F. Known Hazards	**1.** Hazard of suffocation inside GT Enclosure. **2.** Rotating Parts **3.** Explosive atmosphere **4.** Flammable Liquids **5.** High Noise	

G. Competencies	All personnel involved with the job must be familiar with the system and process as well as properly trained for performing the job - **Shutdown of Gas Turbine.**
H. Responsibilities	Shift Charge Engineer will be solely responsible for entire operational process
I. Man Power	**1.** Competent Shift Charge Engineer – for coordination – 01 **2.** Competent Assistant Engineer – for control room operation – 01 **3.** Competent Sub Assistant Engineer – for field operation – 01
J. No of Steps	14 Operation Steps
K. Description of Operation Steps to be followed	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
1.		Confirm that Safety Instructions [Clause-C] is complied.	
2.		If GT is running in OCGT mode, Go to Step-6	
3.		Shutdown ST following SOP for Shutdown of Steam Turbine.	
4.		Shutdown HRSG following SOP for Shutdown of HRSG.	
5.		Ensure Diverter Damper is Closed	
6.		Set Loading / Deloading gradient to 12 MW/Min at CCPP HMI	
7.		Reduce active power to 06 MW	
8.		Reduce Reactive Power and Make Grid Voltage Stable	
9.		Initiate the GT Shutdown sequencer command on GT HMI	

STEP NO.	Pre-Criteria (if any)	Action	Remarks (if any)
10.		Follow actively the On-Screen Instruction on GT HMI	
11.		Ensure i. GCB is Open. [Manually Open if Opening failed in time] ii. Cool-down at Idle Mode for 5 min iii. GT coasting down initiated. iv. Ensure JOP started at 2700 rp0m. v. All Blow-off valves are open vi. Ensure water purging completed. vii. Fuel and NOx water system shut down. viii. FG – LOIL (Lube Oil System) is remained active and lube oil main pump is running	
12.		Carry out field inspection as soon as possible after **Shutdown of Gas Turbine** is completed to ensure plant condition is normal.	
13.		As soon as rotor barring release speed reached, GT is put on rotor barring for a uniform cool down of the rotor. If Rotor Barring failed, Start Manual Rotor Barring within 10 Min	
14.		Physically Check that Rotor is rotating on rotor barring once per hour	
END OF SOP			

4.2.7 SOP for Emergency Blackout and Trip Handling

A. Job Name	**Emergency Blackout and Trip Handling Procedure**
B. Scope	Applicable only for Khulna 225MW CCPP of NWPGCL.
C. Safety Instructions	**1.** Do not be panic. **2.** Be Calm, (if required) use “Deep Breathing” technique to reduce panic. **3.** Use Standard PPE during Field-operation.
D. Responsibilities	Shift Charge Engineer will be solely responsible for entire operational process
E. Man Power	**4.** Competent Shift Charge Engineer – for coordination – 01 **5.** Competent Assistant Engineer – for control room operation – 01 **6.** Competent Sub Assistant Engineer – for field operation – 01
F. Description of Operation Steps to be followed	

Steps	Action
Case-1:	GT Tripped and /or Blackout from CCPP/ OCGT mode Operation **1.** GO TO STEP: **“I. Ensure – GT is in Safe State”** and follow all consecutive Steps.
Case-2:	Only CCPP is Tripped and GT is in Normal Condition / House Load **1.** Ensure that GT GCB is Closed. **2.** GT Parameters are found normal in condition. **3.** GO TO STEP: **“II. Ensure – ST is in Safe State”** and follow all consecutive Steps.
I. Ensure – GT is in Safe State	
1.	Ensure in GT HMI, Emergency DC Lube Oil Pump is running and Lube Oil Header Pressure is approx. 1.7 Bar (after 15 min 0.8 bar).
2.	Reset and Acknowledge GT Trip & PLST.
3.	JOP is Running [if not run from local]

Steps	Action
4.	Rotor Barring is in operation or Ready to Operation in case of GT Coasting Down.
II.	**Ensure – ST is in Safe State**
5.	Ensure Emergency DC Lube Oil Pump is running in ST HMI and Ensure Lube Oil Header Pressure is above 1.0 Bar.
6.	Reset ST Trip
7.	Ensure that a. STG GCB is Opened b. Ensure that HRSG is tripped c. Ensure that Diverter Damper is closed d. All Main Steam Valves and Regulating valves are Closed. e. HP exhaust check valve is closed, f. HP ventilation valve is opened g. TG is in operation or Ready to Operation in case of ST Coasting Down
III.	**Synchronization of GT HVCB from GT House Load [Skip if GT Trip]**
8.	Reset Related all Alarm
9.	Communicate with NLDC
10.	Ensure that Grid has Stable Voltage and Frequency
11.	Synchronize HVCB
12.	Enter GT Load Set Point as per NLDC Demand
13.	Go to Section "VI. Plant Normalization SC Part"
IV.	**Establish Auxiliary Power [Skip if not required and where applicable]**
14.	Start GT EDG [If not started automatically]
15.	Energize SC Emergency [BMA] Bus
16.	Ensure that all GT Emergency Equipment is powered

Steps	Action
17.	Ensure that GT all Emergency Auxiliaries is in normal operation
18.	Start ST EDG [If not started automatically]
19.	Energize CC Emergency [BMA] Bus
20.	Ensure that all ST all Emergency Equipment is powered
21.	Ensure that ST Emergency Auxiliaries is in normal operation
V.	**Plant Normalization OCGT Part**
22.	Reset all Alarms from a. HMI b. All Panels c. All Protection Relays
23.	Ensure that EDG would remain isolated if HVCB is closed
24.	Close HVCB
25.	Sync EDG or the followings a. Open EDG CB b. Close MV Breaker
26.	STOP EDG
27.	Normalize all Breaker Position
VI.	**Plant Normalization CCPP Part**
28.	Reset all Alarms from a. HMI b. All Panels c. All Protection Relays
29.	Ensure that EDG would remain isolated if HVCB is closed
30.	Close HVCB

Steps	Action
31.	Sync EDG or the followings a. Open EDG CB b. Close MV Breaker
32.	STOP EDG
33.	Normalize all Breaker Position
VII.	**<u>Post Check</u>**
34.	Note down all Alarms in Shift Note Book.
35.	Carryout Field Inspection
36.	Prepare Incident Report and Submit

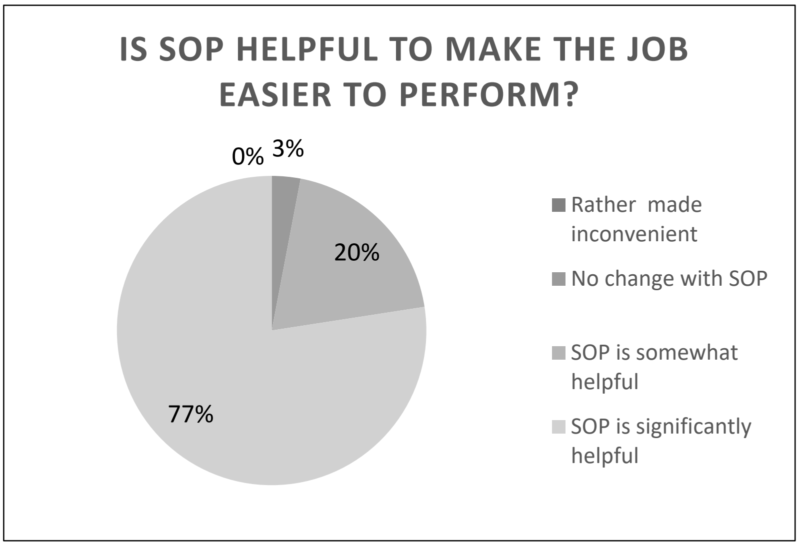
SOP for Weekly Inspection Job has been omitted as a well-developed check-list found in use for operators. This check-list was found serving well in place of a SOP.

4.3 EFFECTS OF SOP

Based on the response of the operators, we can summarize the survey (vide Appendix-B) on the influence of SOP as follows:

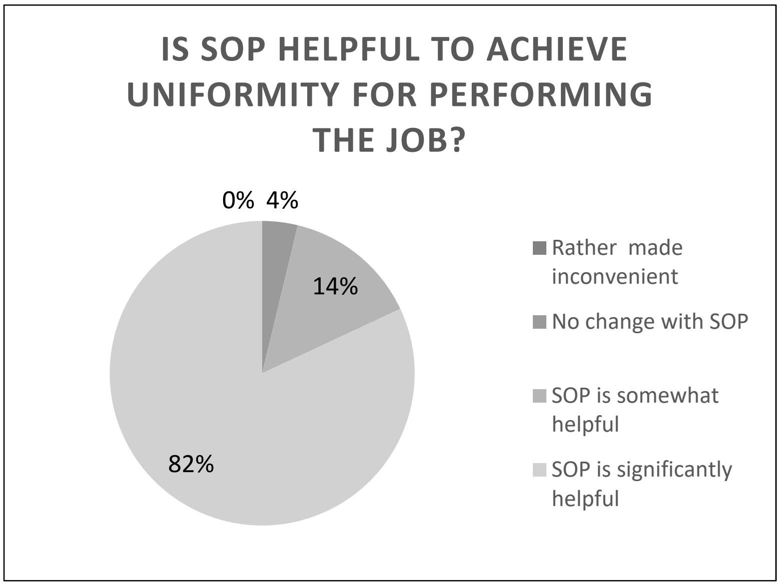
4.3.1 Ease of Operation

In this study we have found that, in 77% cases, SOP has been treated "significantly helpful" to make the job easier. However, in 20% and 3% cases, SOP has found "somewhat helpful" and "no effect" respectively as opined by the operators.



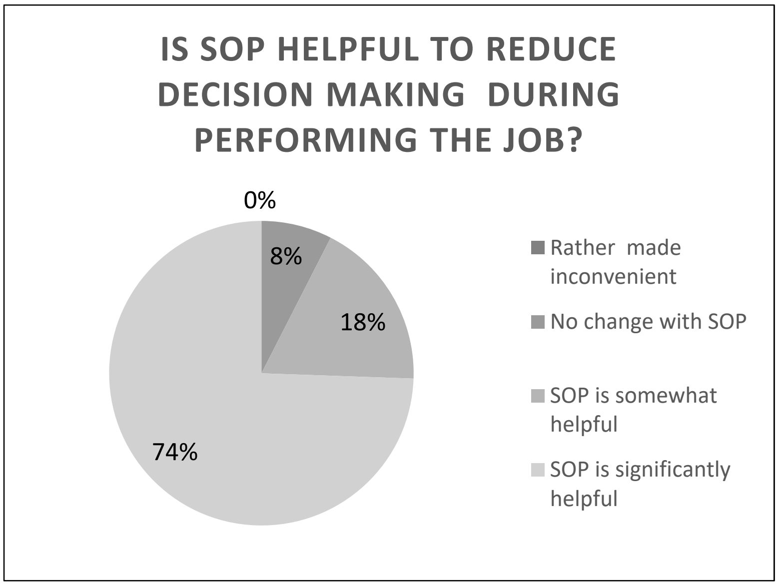
4.3.2 Uniformity of Operation

In response to the questions "Is SOP helpful to achieve uniformity for Performing the job?", 82% cases operators opined that SOP is "significantly helpful". However, in 14% and 4% cases, SOP has found "somewhat helpful" and "no effect" respectively as opined by the operators.



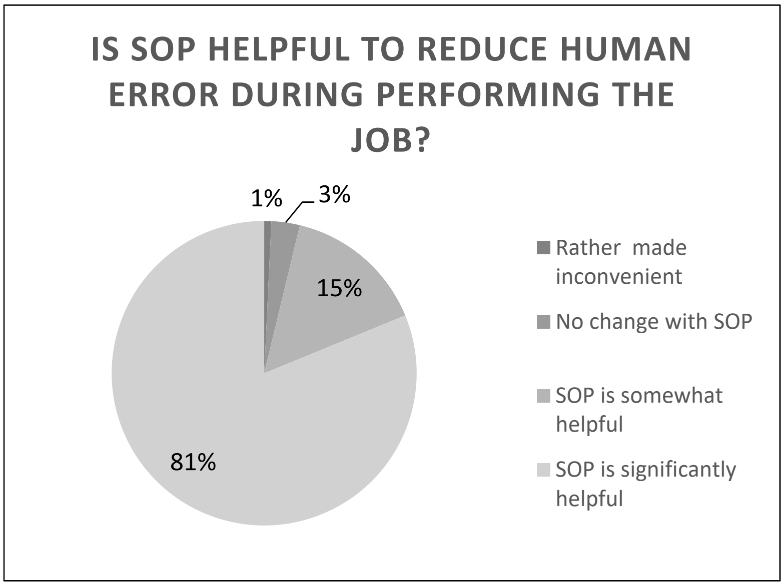
4.3.3 Reduction of Decision Making

In 74% cases, operators opined that SOP is "significantly helpful" when the question of reduction of decision making came. However, in 18% and 8% cases, SOP has found "somewhat helpful" and "no effect" respectively as opined by the operators.



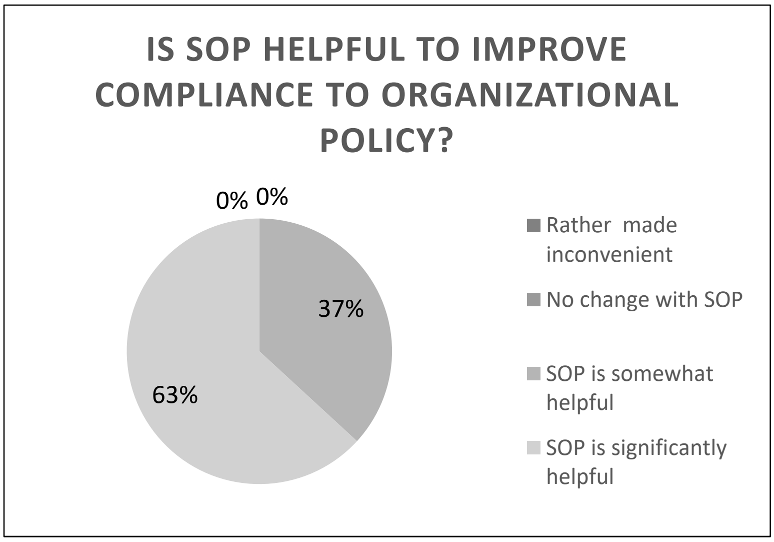
4.3.4 Reduction of Human Error

In this study we have found that, in 81% cases, SOP has been treated "significantly helpful" to reduce human error. However, in 15% and 3% cases, SOP has found "somewhat helpful" and "no effect" respectively as opined by the operators. In 1% cases with this issue, SOP is opined inconvenient.



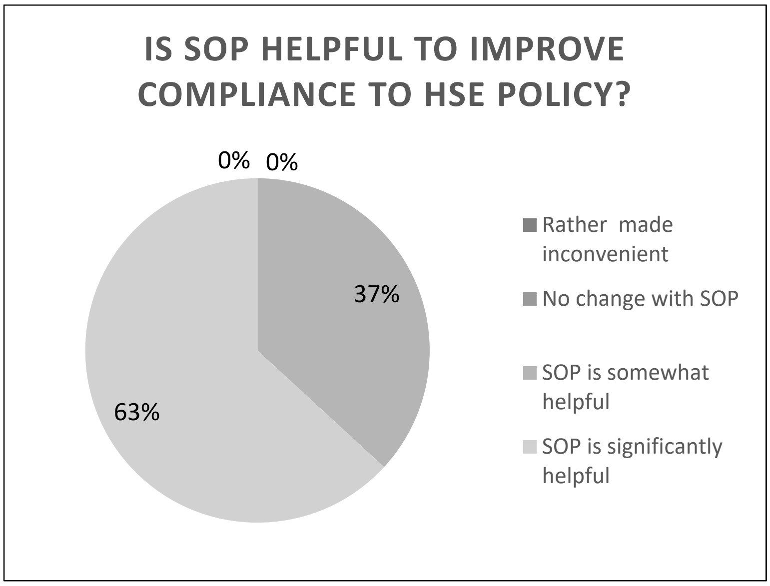
4.3.5 Compliance to Organizational Policy

In 63% cases, operators opined that SOP is "significantly helpful" to comply organizational policy. And in 37% cases, SOP has found "somewhat helpful" as opined by the operators.



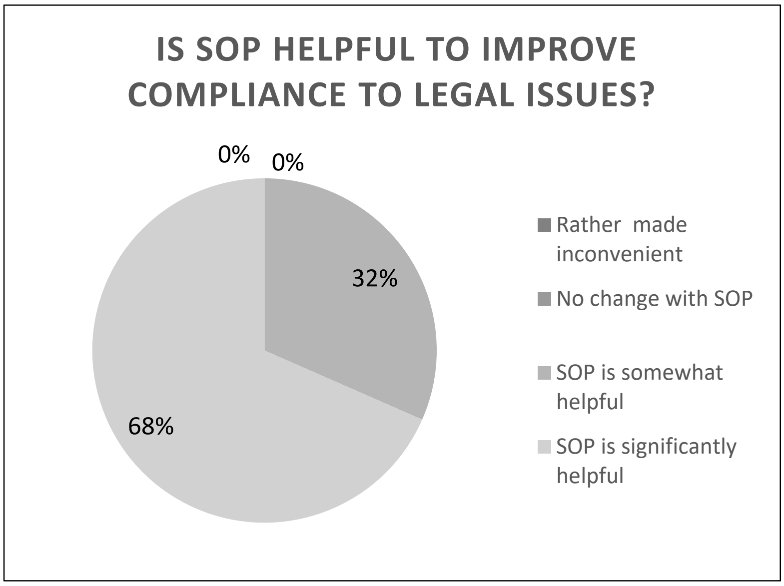
4.3.6 Compliance to HSE Policy

In 63% cases, operators opined that SOP is "significantly helpful" to comply HSE Issues. And in 37% cases, SOP has found "somewhat helpful" as opined by the operators.



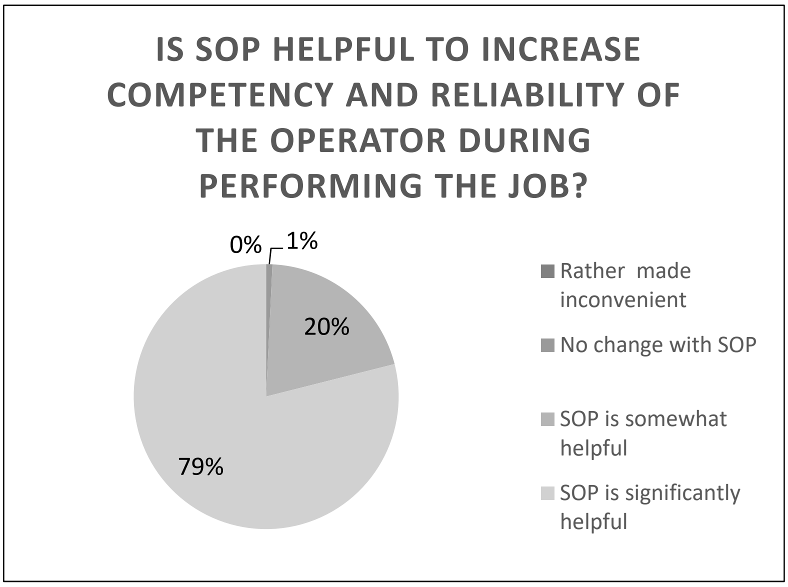
4.3.7 Compliance to Legal Issues

In 63% cases, operators opined that SOP is "significantly helpful" to comply Legal issues. And in 37% cases, SOP has found "somewhat helpful" as opined by the operators.



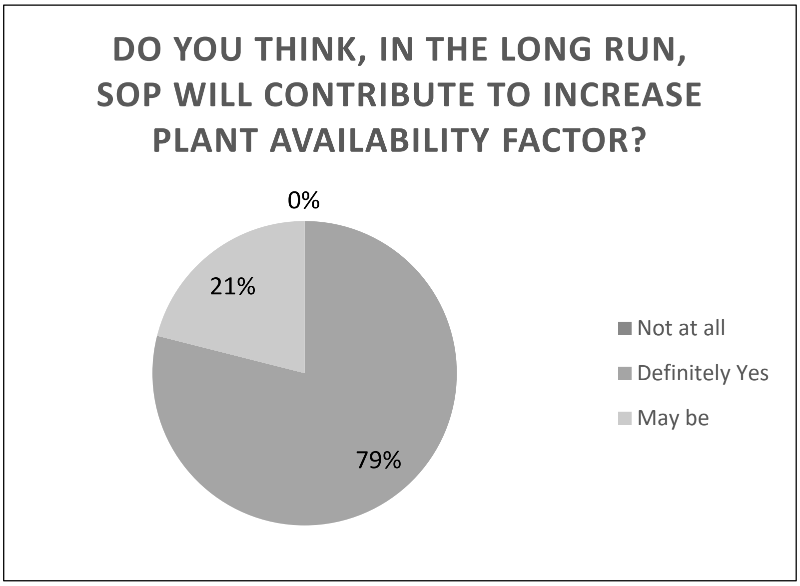
4.3.8 Competency and Reliability of Operator

In response to the questions "Is SOP helpful to increase competency and reliability of the operator during performing the job?", 79% cases operators opined that SOP is "significantly helpful". However, in 20% and 1% cases, SOP has found "somewhat helpful" and "no effect" respectively as opined by the operators.



4.3.9 Increase of Plant Factor

In 79% cases, operators opined that SOP will be "significantly helpful" for increasing plant availability factor in the long run. But, 21% are confused regarding the issues. No body found negative effect of SOP on the issues.



CHAPTER 5: CONCLUSION AND RECOMMENDATION

At this point we can conclude that, SOP is a very good option to standardize the operators' activity to achieve the ease and uniformity of operation with maintaining the compliance related to HSE, legal or company policy related issues. It could also be helpful for reducing human error and to increase the competency and reliability of the operator. When SOP is treated as a tool for reducing human error during operations, we found operators with experience of more than 3 years opined in every case that SOP is significantly helpful.

However, SOP itself could not identify any unsafe or undesired latent condition until such situation occurs during operation. After such an occurrence, a need to change of SOP is identified and might be only after a failure of having desired outcomes or a near-miss or might be after an accident. Periodic brainstorming with SOP among the SMEs (Subject Matter Experts) might be helpful to identify such latent unsafe condition and could be another subject of study.

This is a very primary study for the subject matter. Moreover, scope of this study is in a single combined cycle power plant and only qualitative method has been applied to carry out this study. For an advanced perception regarding the same subject matter this study could be carried out with a numerous number of plant. Again, the outcomes of the study could be justified further with a quantitative analysis with some long-term data.

Again, for the language constraint and due to the limitation of time, this study was carried out based on the opinion of operation engineers only. SOP written in mother language for the staff levels workers might be another field of study. More, interestingly for illiterate worker unable to read in any language could be studied with visual or pictorial SOP.

Considering all above facts, the following recommendations can be made:

1. SOP could be written for every task of the operation engineers
2. SOP could be implemented for Water Treatment Plant Jobs
3. SOP could also be written for routine and preventive maintenance and inspection for all maintenance department.
4. For staff levels worker, SOP for their job could be provided in Bangla Language.
5. Pictorial SOP could be provided for Bottom Level Worker in cleaning jobs.

REFERENCES

[1] PSMP Study Team, "Power System Master Plan 2010," Ministry of Power, Energy and Meneral Resources, People's Republic of Bangladesh, 2011.

[2] M. El-Wakil, Powerplant Technology, McGraw-Hill Book Co, 1985, pp. 72-74.

[3] M. I. Hossain, I. A. Zissan and a. others, "Prospect of combined cycle power plant over conventional single cycle power plants in Bangladesh: A case study," in *International Conference on Electrical Engineering and Information & Communication Technology (ICEEICT)*, April, 2014.

[4] S. C. Arora, S. Domkundwar and A. Domkundwar, A Course in Power Plant Engineering (SI Unit), Dhanpat Rai & Co. (P) Ltd, 2006.

[5] S. N. Yousef, "Efficient use of energy by utilizing gas turbine combined systems," *Applied Thermal Engineering,* 2001.

[6] Guinness World Records, "Most efficient combined cycle power plant," [Online]. Available: http://www.guinnessworldrecords.com/world-records/431420-most-efficient-combined-cycle-power-plant. [Accessed 20 November 2016].

[7] Wikipedia, "Fail-safe," [Online]. Available: https://en.wikipedia.org/wiki/Fail-safe. [Accessed 24 November 2016].

[8] Wikipedia, "Standard operating procedure," [Online]. Available: https://en.wikipedia.org/wiki/Standard_operating_procedure#See_also. [Accessed 21 November 2016].

[9] Center for Chemical Process Safety, Guidelines for Preventing Human Error in Process Safety, New York: American Institute of Chemical Engineers, 1994.

[10] F. A. Abbas and B. Aribowo, "Analysis Of Human Error Probability Using Human Error Assessment & Reduction Technique (Heart) In Dyeing Department Pt. XYZ," in *8th International Seminar on Industrial Engineering and Management*, 2015.

[11] K. Bergerova, "Standard Operating Procedures at Skanska - Standardization and

continuous improvement in the construction industry," Stockholm, Sweden, 2010.

[12] A. A. Hasin, Quality Control and Management, Dhaka, Bangladesh: Bangladesh Business Solution, 2007.

[13] investopedia, "Quality Control," [Online]. Available: http://www.investopedia.com/terms/q/quality-control.asp. [Accessed 31 03 2017].

[14] www.inc.com, "Total Quality Management," [Online]. Available: www.inc.com/encyclopedia/total-quality-management-tqm.html. [Accessed 11 April 2017].

[15] A. R. Martínez-Lorente and Dewhurst, Frank, "Total Quality Management: Origins and Evolution of the Term," *The TQM Magazine,* vol. 10 no. 5, p. 378–386, 1998.

[16] Wikipedia, "Total Quality Management," [Online]. Available: https://en.wikipedia.org/wiki/Total_quality_management. [Accessed 15 March 2017].

[17] Wikipedia, "5S (Methodology)," [Online]. Available: https://en.wikipedia.org/wiki/5S_(methodology). [Accessed 16 April 2017].

[18] iSixSigma, "A Practical Approach to the Successful Practice of 5S," [Online]. Available: https://www.isixsigma.com/tools-templates/5s/practical-approach-successful-practice-5s/. [Accessed 16 April 2017].

[19] investopedia, "Kaizen," [Online]. Available: www.investopedia.com/terms/k/kaizen.asp. [Accessed 13 April 2017].

[20] M. Imai, Kaizen – The Key To Japan's Competitive Success, New York: Random House, 1986.

[21] "K A I Z E N Masaaki Imai," slideshare, [Online]. Available: https://www.slideshare.net/trisetyawati/k-a-i-z-e-n-masaaki-imai. [Accessed 17 03 2017].

[22] Brunsson, N. and Jakobsson, B., Standardisering, Stockholm: Nerenius & Santérus förlag, 1998.

[23] Wikipedia, "Great_Train_Wreck_of_1856," [Online]. Available:

https://en.wikipedia.org/wiki/Great_Train_Wreck_of_1856. [Accessed 22 November 2016].

[24] zapier.com, "Don't Overlook Standard Operating Procedures: Use These Apps to Put Them in Place," [Online]. Available: https://zapier.com/learn/project-management/standard-operating-procedures/. [Accessed 25 January 2017].

[25] Chron, "What is ISO Certification," [Online]. Available: http://smallbusiness.chron.com/iso-certification-43217.html. [Accessed 17 03 2017].

[26] D. N. HTCT683918, *Operating Instruction for the Alstom Gas Turbine GT13E2 within the 150MW Peaking Power Plant of Khulna.*

APPENDIX-A: QUESTIONNAIRE TO STUDY OPERATORS' JOB

Stage-1 Survey#1: Khulna 225MW CCPP - Evaluating Operational Routine Activities

I, K.M.M. Resalat Rajib am currently pursuing my M.Sc. in Industrial Engineering and Management in Khulna University of Engineering and Technology under the supervision of Professor Dr. Kutub Uddin. This survey questionnaire is designed for the research work for the said degree and is intended only for Operation personnel who worked or is working in Khulna 225MW CCPP. This survey will take approximately 15 min from you.

* Required

Personal Data

1. **Your Name** *

   ____

2. **Email (Optional)**

   ____

3. **Your Designation (or Equivalent) during serving in Operation Department** *
   Mark only one oval.

   - ◯ Sub-Divisional Engineer
   - ◯ Assistant Engineer
   - ◯ Sub Assistant Engineer
   - ◯ Work Assistant / Others

4. **Please Specify your years of Experience of Operation in this Power Plant** *
   Mark only one oval.

   - ◯ Less than 1 Year
   - ◯ 1 to 2 Years
   - ◯ 2 to 3 Years
   - ◯ More than 3 Years

5. **Please Specify your total years of Experience in Power Plant Operation** *
   Mark only one oval.

   - ◯ Less than 1 Year
   - ◯ 1 to 2 Years
   - ◯ 2 to 3 Years
   - ◯ More than 3 Years

6. **Please Specify your Highest Educational Qualification** *
Mark only one oval.

- ⬭ Post Graduate or Above
- ⬭ Under Graduate
- ⬭ Diploma
- ⬭ HSC / SSC
- ⬭ Less than SSC

Startup of Gas Turbine

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

7. **Complexity of the Job**
Mark only one oval.

	1	2	3	4	5	
Very Simple	⬭	⬭	⬭	⬭	⬭	Most Complex

8. **Requirement of Decision Making**
Mark only one oval.

	1	2	3	4	5	
very little	⬭	⬭	⬭	⬭	⬭	Extensive decision making is involved

9. **Is quality assured for the job?**
Mark only one oval.

	1	2	3	4	5	
Not Assured	⬭	⬭	⬭	⬭	⬭	Assured totally

10. **How the performance of operator vary from one Operator to another?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

11. **How the performance of a single operator vary from time to time?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

12. **Level of compliance maintained during the job for below respective issues**
Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	◯	◯	◯	◯	◯
Safety	◯	◯	◯	◯	◯
Environment	◯	◯	◯	◯	◯
Legal Issues	◯	◯	◯	◯	◯
Company Police	◯	◯	◯	◯	◯

13. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	◯	◯	◯	◯	◯	Significant Hazard

14. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- [ ] Fatal Accident
- [ ] Damage to Major Equipment
- [ ] Harmful to Major Equipment
- [ ] Damage to Auxiliary Equipment
- [ ] Harmful to Auxiliary Equipment
- [ ] Injury
- [ ] Outage
- [ ] Fire or any other Severe Major Accident
- [ ] Minor Accident
- [ ] Nil (No major Issues could be foretasted)

Startup of Heat Recovery Steam Generator (HRSG)

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

15. **Complexity of the Job**
Mark only one oval.

	1	2	3	4	5	
Very Simple	◯	◯	◯	◯	◯	Most Complex

16. **Requirement of Decision Making**
Mark only one oval.

	1	2	3	4	5	
very little	◯	◯	◯	◯	◯	Extensive decision making is involved

17. **Is quality assured for the job?**
Mark only one oval.

	1	2	3	4	5	
Not Assured	⬭	⬭	⬭	⬭	⬭	Assured totally

18. **How the performance of operator vary from one Operator to another?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

19. **How the performance of a single operator vary from time to time?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

20. **Level of compliance maintained during the job for below respective issues**
Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	⬭	⬭	⬭	⬭	⬭
Safety	⬭	⬭	⬭	⬭	⬭
Environment	⬭	⬭	⬭	⬭	⬭
Legal Issues	⬭	⬭	⬭	⬭	⬭
Company Police	⬭	⬭	⬭	⬭	⬭

21. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	⬭	⬭	⬭	⬭	⬭	Significant Hazard

22. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- ☐ Fatal Accident
- ☐ Damage to Major Equipment
- ☐ Harmful to Major Equipment
- ☐ Damage to Auxiliary Equipment
- ☐ Harmful to Auxiliary Equipment
- ☐ Injury
- ☐ Outage
- ☐ Fire or any other Severe Major Accident
- ☐ Minor Accident
- ☐ Nil (No major Issues could be foretasted)

Startup of Steam Turbine

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

23. **Complexity of the Job**

Mark only one oval.

	1	2	3	4	5	
Very Simple	◯	◯	◯	◯	◯	Most Complex

24. **Requirement of Decision Making**

Mark only one oval.

	1	2	3	4	5	
very little	◯	◯	◯	◯	◯	Extensive decision making is involved

25. **Is quality assured for the job?**

Mark only one oval.

	1	2	3	4	5	
Not Assured	◯	◯	◯	◯	◯	Assured totally

26. **How the performance of operator vary from one Operator to another?**

Mark only one oval.

	1	2	3	4	5	
Uniform	◯	◯	◯	◯	◯	Significantly Vary

27. **How the performance of a single operator vary from time to time?**

Mark only one oval.

	1	2	3	4	5	
Uniform	◯	◯	◯	◯	◯	Significantly Vary

28. **Level of compliance maintained during the job for below respective issues**

Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	◯	◯	◯	◯	◯
Safety	◯	◯	◯	◯	◯
Environment	◯	◯	◯	◯	◯
Legal Issues	◯	◯	◯	◯	◯
Company Police	◯	◯	◯	◯	◯

29. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	⬭	⬭	⬭	⬭	⬭	Significant Hazard

30. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- [ ] Fatal Accident
- [ ] Damage to Major Equipment
- [ ] Harmful to Major Equipment
- [ ] Damage to Auxiliary Equipment
- [ ] Harmful to Auxiliary Equipment
- [ ] Injury
- [ ] Outage
- [ ] Fire or any other Severe Major Accident
- [ ] Minor Accident
- [ ] Nil (No major Issues could be foretasted)

Shut Down of Gas Turbine

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

31. **Complexity of the Job**
Mark only one oval.

	1	2	3	4	5	
Very Simple	⬭	⬭	⬭	⬭	⬭	Most Complex

32. **Requirement of Decision Making**
Mark only one oval.

	1	2	3	4	5	
very little	⬭	⬭	⬭	⬭	⬭	Extensive decision making is involved

33. **Is quality assured for the job?**
Mark only one oval.

	1	2	3	4	5	
Not Assured	⬭	⬭	⬭	⬭	⬭	Assured totally

34. **How the performance of operator vary from one Operator to another?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

40. **Requirement of Decision Making**
Mark only one oval.

	1	2	3	4	5	
very little	⬭	⬭	⬭	⬭	⬭	Extensive decision making is involved

41. **Is quality assured for the job?**
Mark only one oval.

	1	2	3	4	5	
Not Assured	⬭	⬭	⬭	⬭	⬭	Assured totally

42. **How the performance of operator vary from one Operator to another?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

43. **How the performance of a single operator vary from time to time?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

44. **Level of compliance maintained during the job for below respective issues**
Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	⬭	⬭	⬭	⬭	⬭
Safety	⬭	⬭	⬭	⬭	⬭
Environment	⬭	⬭	⬭	⬭	⬭
Legal Issues	⬭	⬭	⬭	⬭	⬭
Company Police	⬭	⬭	⬭	⬭	⬭

45. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	⬭	⬭	⬭	⬭	⬭	Significant Hazard

35. **How the performance of a single operator vary from time to time?**
Mark only one oval.

	1	2	3	4	5	
Uniform	◯	◯	◯	◯	◯	Significantly Vary

36. **Level of compliance maintained during the job for below respective issues**
Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	◯	◯	◯	◯	◯
Safety	◯	◯	◯	◯	◯
Environment	◯	◯	◯	◯	◯
Legal Issues	◯	◯	◯	◯	◯
Company Police	◯	◯	◯	◯	◯

37. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	◯	◯	◯	◯	◯	Significant Hazard

38. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- [ ] Fatal Accident
- [ ] Damage to Major Equipment
- [ ] Harmful to Major Equipment
- [ ] Damage to Auxiliary Equipment
- [ ] Harmful to Auxiliary Equipment
- [ ] Injury
- [ ] Outage
- [ ] Fire or any other Severe Major Accident
- [ ] Minor Accident
- [ ] Nil (No major Issues could be foretasted)

Shut Down of HRSG

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

39. **Complexity of the Job**
Mark only one oval.

	1	2	3	4	5	
Very Simple	◯	◯	◯	◯	◯	Most Complex

46. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- [ ] Fatal Accident
- [ ] Damage to Major Equipment
- [ ] Harmful to Major Equipment
- [ ] Damage to Auxiliary Equipment
- [ ] Harmful to Auxiliary Equipment
- [ ] Injury
- [ ] Outage
- [ ] Fire or any other Severe Major Accident
- [ ] Minor Accident
- [ ] Nil (No major Issues could be foretasted)

Shut Down of Steam Turbine

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

47. **Complexity of the Job**
Mark only one oval.

	1	2	3	4	5	
Very Simple	⬭	⬭	⬭	⬭	⬭	Most Complex

48. **Requirement of Decision Making**
Mark only one oval.

	1	2	3	4	5	
very little	⬭	⬭	⬭	⬭	⬭	Extensive decision making is involved

49. **Is quality assured for the job?**
Mark only one oval.

	1	2	3	4	5	
Not Assured	⬭	⬭	⬭	⬭	⬭	Assured totally

50. **How the performance of operator vary from one Operator to another?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

51. **How the performance of a single operator vary from time to time?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

52. **Level of compliance maintained during the job for below respective issues**
Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	◯	◯	◯	◯	◯
Safety	◯	◯	◯	◯	◯
Environment	◯	◯	◯	◯	◯
Legal Issues	◯	◯	◯	◯	◯
Company Police	◯	◯	◯	◯	◯

53. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	◯	◯	◯	◯	◯	Significant Hazard

54. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- [ ] Fatal Accident
- [ ] Damage to Major Equipment
- [ ] Harmful to Major Equipment
- [ ] Damage to Auxiliary Equipment
- [ ] Harmful to Auxiliary Equipment
- [ ] Injury
- [ ] Outage
- [ ] Fire or any other Severe Major Accident
- [ ] Minor Accident
- [ ] Nil (No major Issues could be foretasted)

Blackout Response

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

55. **Complexity of the Job**
Mark only one oval.

	1	2	3	4	5	
Very Simple	◯	◯	◯	◯	◯	Most Complex

56. **Requirement of Decision Making**
Mark only one oval.

	1	2	3	4	5	
very little	◯	◯	◯	◯	◯	Extensive decision making is involved

57. **Is quality assured for the job?**
Mark only one oval.

	1	2	3	4	5	
Not Assured	⬭	⬭	⬭	⬭	⬭	Assured totally

58. **How the performance of operator vary from one Operator to another?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

59. **How the performance of a single operator vary from time to time?**
Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

60. **Level of compliance maintained during the job for below respective issues**
Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	⬭	⬭	⬭	⬭	⬭
Safety	⬭	⬭	⬭	⬭	⬭
Environment	⬭	⬭	⬭	⬭	⬭
Legal Issues	⬭	⬭	⬭	⬭	⬭
Company Police	⬭	⬭	⬭	⬭	⬭

61. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	⬭	⬭	⬭	⬭	⬭	Significantly Vary

62. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- [ ] Fatal Accident
- [ ] Damage to Major Equipment
- [ ] Harmful to Major Equipment
- [ ] Damage to Auxiliary Equipment
- [ ] Harmful to Auxiliary Equipment
- [ ] Injury
- [ ] Outage
- [ ] Fire or any other Severe Major Accident
- [ ] Minor Accident
- [ ] Nil (No major Issues could be foretasted)

Weekly Inspection

Please select the answer that fit best at present according to your understanding based on your knowledge and experience

63. **Complexity of the Job**

Mark only one oval.

	1	2	3	4	5	
Very Simple	⬭	⬭	⬭	⬭	⬭	Most Complex

64. **Requirement of Decision Making**

Mark only one oval.

	1	2	3	4	5	
very little	⬭	⬭	⬭	⬭	⬭	Extensive decision making is involved

65. **Is quality assured for the job?**

Mark only one oval.

	1	2	3	4	5	
Not Assured	⬭	⬭	⬭	⬭	⬭	Assured totally

66. **How the performance of operator vary from one Operator to another?**

Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

67. **How the performance of a single operator vary from time to time?**

Mark only one oval.

	1	2	3	4	5	
Uniform	⬭	⬭	⬭	⬭	⬭	Significantly Vary

68. **Level of compliance maintained during the job for below respective issues**

Mark only one oval per row.

	Not Applicable	Not at all	Poor	Good	Excellent
Health	⬭	⬭	⬭	⬭	⬭
Safety	⬭	⬭	⬭	⬭	⬭
Environment	⬭	⬭	⬭	⬭	⬭
Legal Issues	⬭	⬭	⬭	⬭	⬭
Company Police	⬭	⬭	⬭	⬭	⬭

69. **Hazard involved with this job**
Mark only one oval.

	1	2	3	4	5	
No Hazard	⬭	⬭	⬭	⬭	⬭	Significant Hazard

70. **Probable consequence of failure to carry out the job correctly**
Check all that apply.

- ☐ Fatal Accident
- ☐ Damage to Major Equipment
- ☐ Harmful to Major Equipment
- ☐ Damage to Auxiliary Equipment
- ☐ Harmful to Auxiliary Equipment
- ☐ Injury
- ☐ Outage
- ☐ Fire or any other Severe Major Accident
- ☐ Minor Accident
- ☐ Nil (No major Issues could be foretasted)

Please Click Submit below. Survey#1 is completed. Thanks for your participation and kind response.

APPENDIX-B: QUESTIONNAIRE TO STUDY THE EFFECT OF SOP

Stage-2 Survey#1: Khulna 225MW CCPP - Influence of SOP on Operational Activities

I, K.M.M. Resalat Rajib am currently pursuing my M.Sc. in Industrial Engineering and Management in Khulna University of Engineering and Technology under the supervision of Professor Dr. Kutub Uddin. This survey questionnaire is designed for the research work for the said degree and is intended only for Operation personnel who worked or is working in Khulna 225MW CCPP. This survey will take approximately 15 min from you.

* Required

Personal Data

1. **Your Name** *

2. **Email** *

3. **Your Designation (or Equivalent) during serving in Operation Department** *
Mark only one oval.
   - Sub-Divisional Engineer
   - Assistant Engineer
   - Sub Assistant Engineer

4. **Please Specify your total years of Experience in Power Plant Operation** *
Mark only one oval.
   - Less than 1 Year
   - 1 to 2 Years
   - 2 to 3 Years
   - More than 3 Years

5. **Please Specify your Highest Educational Qualification** *
Mark only one oval.
   - Post Graduate or Above
   - Under Graduate
   - Diploma

Evaluation: Based on your knowledge and experience, Answer the followings that fit best in your opinion for each job

6. **Q-01. How Complex the job is to perform without a SOP?** *
Mark only one oval per row.

	Very Simple	Somewhat Simple	Somewhat Complex	Very Complex
Startup of GT				
Startup of HRSG				
Startup of ST				
Shutdown of GT				
Shutdown of HRSG				
Shutdown of ST				
Emergency Blackout & Trip Handling				

7. **Q-02. How much decision making is involved during performing the job without a SOP?** *
Mark only one oval per row.

	No or least decision making	Moderate decision making	Significant decision making
Startup of GT			
Startup of HRSG			
Startup of ST			
Shutdown of GT			
Shutdown of HRSG			
Shutdown of ST			
Emergency Blackout & Trip Handling			

8. **Q-03. Is SOP helpful to make the Job easier to perform?** *
Mark only one oval per row.

	Rather made inconvenient	No change with SOP	SOP is somewhat helpful	SOP is significantly helpful
Startup of GT				
Startup of HRSG				
Startup of ST				
Shutdown of GT				
Shutdown of HRSG				
Shutdown of ST				
Emergency Blackout & Trip Handling				

9. **Q-04. Is SOP helpful to achieve uniformity for Performing the job?** *
Mark only one oval per row.

	Rather made inconvenient	No change with SOP	SOP is somewhat helpful	SOP is significantly helpful
Startup of GT				
Startup of HRSG				
Startup of ST				
Shutdown of GT				
Shutdown of HRSG				
Shutdown of ST				
Emergency Blackout & Trip Handling				

10. **Q-05. Is SOP helpful to reduce decision making during performing the job?** *
Mark only one oval per row.

	Rather made inconvenient	No change with SOP	SOP is somewhat helpful	SOP is significantly helpful
Startup of GT	◯	◯	◯	◯
Startup of HRSG	◯	◯	◯	◯
Startup of ST	◯	◯	◯	◯
Shutdown of GT	◯	◯	◯	◯
Shutdown of HRSG	◯	◯	◯	◯
Shutdown of ST	◯	◯	◯	◯
Emergency Blackout & Trip Handling	◯	◯	◯	◯

11. **Q-06. Is SOP helpful to reduce human error during performing the job?** *
Mark only one oval per row.

	Rather made inconvenient	No change with SOP	SOP is somewhat helpful	SOP is significantly helpful
Startup of GT	◯	◯	◯	◯
Startup of HRSG	◯	◯	◯	◯
Startup of ST	◯	◯	◯	◯
Shutdown of GT	◯	◯	◯	◯
Shutdown of HRSG	◯	◯	◯	◯
Shutdown of ST	◯	◯	◯	◯
Emergency Blackout & Trip Handling	◯	◯	◯	◯

12. **Q-07. Is SOP helpful to improve compliance to organizational policy?** *
Mark only one oval.

◯ Rather made inconvenient
◯ No change with SOP
◯ SOP is somewhat helpful
◯ SOP is significantly helpful

13. **Q-08. Is SOP helpful to improve compliance to HSE policy?** *
Mark only one oval.

◯ Rather made inconvenient
◯ No change with SOP
◯ SOP is somewhat helpful
◯ SOP is significantly helpful

14. **Q-09. Is SOP helpful to improve compliance to Legal Issues?** *
Mark only one oval.

◯ Rather made inconvenient
◯ No change with SOP
◯ SOP is somewhat helpful
◯ SOP is significantly helpful

15. **Q-10. Is SOP helpful to increase competency and reliability of the operator during performing the job?** *
Mark only one oval per row.

	Rather made inconvenient	No change with SOP	SOP is somewhat helpful	SOP is significantly helpful
Startup of GT	◯	◯	◯	◯
Startup of HRSG	◯	◯	◯	◯
Startup of ST	◯	◯	◯	◯
Shutdown of GT	◯	◯	◯	◯
Shutdown of HRSG	◯	◯	◯	◯
Shutdown of ST	◯	◯	◯	◯
Emergency Blackout & Trip Handling	◯	◯	◯	◯

16. **Q-11. Do you think, in the long run, SOP will contribute to increase Plant Availability Factor?** *
Mark only one oval.

- ◯ Not at all
- ◯ May be
- ◯ Definitely Yes

Thanks for your participation and kind response.The Survey is completed. Please Click Submit below.

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