igef Indo-German Energy Forum

EEC Excellence in Power

Required Training for Flexible Operation of Coal Fired Power Plants in India

Partner :

KWS PowerTech Training Center

Supported by:

Government of India
Ministry of New and Renewable Energy

Federal Ministry for Economic Affairs and Energy

Imprint

Commissioned by
Excellence Enhancement Centre for Indian Power Sector (EEC)
West Block - 2, First Floor
Wing No. 5, Sector 1, R.K. Puram
New Delhi 110066, India
Email: info@eecpowerindia.com
Webite: www.eecpowerindia.com
Tel.: +91 11 26164297 - 95

Indo-German Energy Forum Support Office
c/o Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
1st Floor, B-5/2, Safdarjung Enclave
New Delhi 110 029, India
Email: info@energyforum.in
Webite: www.energyforum.in
Tel.: +91 11 4949 5353

Project Lead
O.P. Maken, Tobias Winter

Report by
KRAFTWERKSSCHULE E.V.
Deilbachtal 199
D-45257 Essen, Germany
Website: www.kraftwerksschule.de

Contact
Dr.-Ing. Dariush Hourfar, KWS Essen
Dipl.-Ing. Hans-Werner Otte, KWS Essen

Version: Essen, 09 June 2017; Rev. 1.2

Table of Contents

List of Figures 02

1. Preface 03

2. Concept and methods of training 04
2.1 Operating personnel qualification requirements 04
2.2 Assessment of participants 05
2.3 Groups of training participants and general training objectives 06
2.3.1 Management personnel 06
2.3.2 Operating staff 06
2.3.3 Technical staff 07
2.3.4 Operations and grid coordinators and Maintenance Coordinators 07
2.4 The four components of implementation measures 08
2.4.1 Training 08
2.4.2 Follow-up 08
2.4.3 Qualification and Competence Development Programs 08
2.4.4 Lessons learnt for the future 08
2.5 Training and instruction methodology 11
2.5.1 Faculty training for Indian Trainers 11
2.6 Training objectives recommended for this project 12
2.7 Training materials - handouts 15
2.8 Proposal for the categorization of Indian power plants into four service groups 15
2.9 Learning tests 16

3. Quality management system and methodology 18
3.1 Conducting and Controlling 18
3.2 Quality Cycle 19
3.2.1 PDCA 19
3.3 Three Stage approach 20
3.3.1 Project Controlling (Stage 1) 21
3.3.2 Personnel Development Controlling (Stage 2) 21
3.3.3 Conduction and performance Controlling (Stage 3) 22

4. Training Modules 23
4.1 Preparation Modules 23
4.1.1 Boiler Design and Firing System 23
4.1.2 Design and Operation 24
4.1.3 Steam Turbine System 25
4.1.4 Electrical Systems 26
4.1.5 Renewable Energy Systems and feed-in behavior 32
4.1.6 Electricity Market and Generation Cost 33
4.2 Fexibility Modules 34
4.2.1 Boiler Operation 34
4.2.2 One Mill Operation 36
4.2.3 Electrical operations under extraordinary load and outage conditions 37
4.2.4 Maintenance Procedures and Strategies 40
4.3 Simulator Modules 42
4.4 Competency Modules 45
4.4.1 Maintenance Procedures and Strategies 45
4.4.2 Grid Coordination 47
4.4.3 Train the Trainer 49
4.4.4 Instruct the Trainer 50

5. Recommendations, next Steps and way forward 52

List of Figures

Figure 1 : Assessment Process 05
Figure 2 : PDCA Cycle 20
Figure 3 : Quality management 22

1. Preface

With the rapid expansion of India´s renewable power plant capacities and the increasing complexity of power plant technology, the need for standardized and customized high-quality personnel training throughout the industry is evident. The necessity of training is based on clear recommendations described in this report.

The recommended training plan covers a wide range of technical topics for different design types of coal fired power plants. Specific simulator training enables participants to actively and purposefully apply the knowledge and skills they have acquired in theory. The developed training program strictly adheres to all occupational safety requirements. Environmental protection and resource conservation standards as well as business-specific demands in the fields of operations, planning, maintenance and repairs are observed.

“Train and instruct the Trainer” will be an important part to prepare Indian trainers for the future challenges in the power generation market during the transition phase.

2. Concept and methods of training

Germany's electricity supply system is probably the safest and most reliable in the world also because plant attendants, control room operators and shift supervisors are graduates of a comprehensive and thorough vocational training system.

Control room operators have had typically an initial 3 years vocational training as mechanics or electricians at the plant itself and at Germanys Power Tech Training Center. The German Power Tech Training Center's mission is to train operating personnel of power plants, particularly control room operators and shift supervisorsin accordance with the guidelines of Europe's power plant association VGB.

The theoretical part of this training takes place in instruction courses. Since 1986, training in the field of fossil-fired power plants in Germany has been complemented by hands-on simulator training. Simulators reproduce a power plant's control room operations comprehensively with all components and their interaction in particular.

2.1 Operating Personnel Qualification Requirements

Power plant personnel training has always been a high-priority issue all over the world. Training contents comprise process engineering, production engineering, and maintenance engineering aspects complemented by such topics as managerial standards and regulations as well as governmental requirements.

Power plant complexity is bound to increase. Advanced process and control engineering technology will result in higher degrees of plant efficiency. Due to future market competition in India, power plant staffs may be downsized and automation will take even greater inroads in power plant operations. Data acquired and processed by modern computer systems are thoroughly evaluated and acted upon accordingly by fewer plant employees. The operating staff nowadays has developed an understanding of power plant installations and their maintenance as a whole.

This means that the operating staff will increasingly consist of generalists as opposed to specialists, a result of ever greater plant complexity. Power plant operators will need to know all systems of their facility and how to operate them. Consequently, operating personnel qualification demands will rise, which includes this project as well. New technologies always necessitate continuous adjustment of personnel skills and knowledge. Staffers must be willing to keep on learning all the time. The major objective of this project is to prepare the well-trained power plant staff in India for the challenges of the variable and intermittent power generation from renewable energy sources. Fossil-fired power plants have to cope with the issues connected with this new source of electrical energy by maintaining the necessary balance in the Indian power supply system. They must be capable of increasing and decreasing output very quickly and reduce the minimum load compared to its previous limits. The operating staff has to manage operating conditions of the whole plant during those very challenging operations procedures. In addition, every staff member of a fossil-fired power plant needs to understand and accept that maximum output is no longer the key business objective in plant operations. Instead, decreasing load may be more efficient under certain grid conditions.

The training concept proposed for India complies the following demands:

- Operation of power plants during load ramps
- Operation of power plants at minimum load conditions

- Operation of power plants beyond the known limits of operation
- Effects of flexible operation on the efficiency of the power plant
- Primary and secondary load- and frequency control
- Functionality of voltage control under different modes of operation of the power plants und different grid conditions
- Operation of boilers and turbines during island operation of the plants
- Reestablishment of the electrical grid after black out conditions
- Adjustment of maintenance and service measures and strategies

2.2 Assessment Of Participants

Assessments are typically designed for different levels of proficiency and assignment-specific. The goals have to be clearly defined to ensure that the result meets the client's expectations (e.g. German or European standard). Practical experience shows that a combination of written and oral tests is most likely to be used.

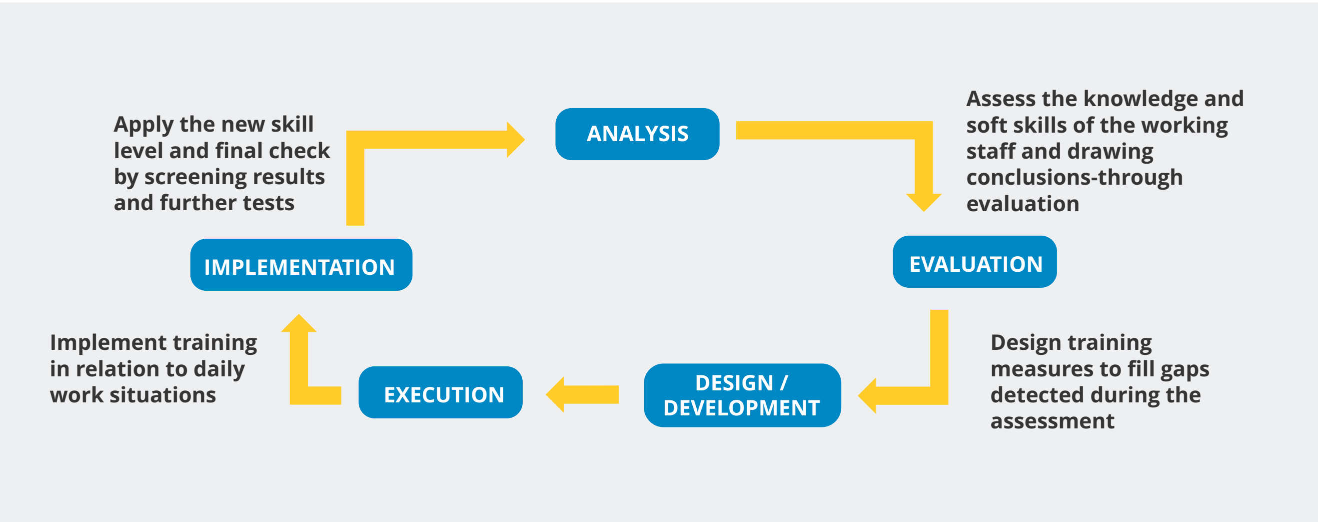
The basic assessment of power plant personnel will be based on a variety of technical and general knowledge and consists of a written test on power plant technology and a discussion of technical matters participants should be familiar with from their daily work.Shift supervisors will go through written tests in technology, general knowledge, economics and soft skills. They will have to pass a practical soft skills test segment as well and are interviewed by several experts from different branches of the power plant staff.

Management audits are the highest level of assessment and have to be prepared very carefully. For greater validity, these audits are mostly conducted by outside companies. Audits will be one-on-one or group events depending on the task at hand. Since the main intention of an audit is to evaluate leadership and social skills of managers, careful observation is called for. In this particular project, management audits are not a key issue.

The assessments will produce a well-founded analysis of training needs, to be followed by a customized instruction program, which is described in the following chapters of this report. Also, an assessment should determine whether participants are fit for training or if preparation courses are in order.Assessments will be designed to determine the trainees' level of existing knowledge and reveal knowledge gaps in the relevant topics for flexible operations and load management. At the end of his assessment, each participant will get proper feedback.

A concept that fulfills the requirements of this project has already been successfully inaugurated and put to use several times. Appropriate training plans for other projects have been successfully developed based on such assessments.

Figure 1 Assessment Process



It is recommended to subdivide the staff of the selected Indian fossil-fired power plants into four groups. For each group, general training objectives have been defined based on experience gained in Germany's "Energiewende" in German power plants, preparing personnel for the challenges of an open and volatile "energy only" market.

2.3 Groups Of Training Participants And General Training Objectives

- Management personnel (senior management, senior engineers, etc.)
- Operating staff (shift supervisors, control room personnel, local operators)
- Technical staff (maintenance: mechanical, electrical and automation)
- Operations and grid coordinators

2.3.1 Management Personnel

Specialized training for business management and for handling the technical and operational limitations of flexible production caused by participating in the flexibility program (ancillary grid services) is recommended for senior management staff. In addition, emergency management rehearsals for blackout conditions, black start and grid restoration procedures are also recommended.

2.3.2 Operating Staff

Control room personnel are the key target group of the flexibility program.Today's control room is the center of communication where more and more strands of information converge in a power plant's operations. Starting out as the center for acquiring information from the plant process from process control and regulation as well as a deployment center for a power plant's personnel, it has become the nerve center of process and operations management. Cost reduction efforts, especially, have been speeding up the ongoing amalgamation of assignments in centralized control rooms.

On the one hand, the centralization of assignments, enabled by advanced control engineering and computer technologies, makes quick and effective mastery of complex processes needed for the flexibility program in India possible. A comprehensive overview of on-site process conditions maximizes operational results and consequently the effective degree of efficiency of a complete facility. Early detection of process and critical situations increases a plant's availability for fast ramp-ups and -downs and helps the operator of the facility realize higher profits in the new evolving market. On the other hand, a control room's intelligence is still provided by man (well-trained and well- prepared), who makes all vital decisions within a given framework and ascertains that a facility operates optimally.

Methods to facilitate quick and confident decisions have made significant inroads into modern instruction efforts. Today's training courses are unthinkable without them. Those methods will be employed in this project.

Last, but not least, a control room is the heart of a power plant and therefore an object of exhibition. Consequently, control rooms are increasingly put on display in most industrialized countries. Due to the increasing importance of public relations efforts, it becomes a showpiece for its parent company to be scrutinized and admired by visitors as a reflection of advanced technologies and a mirror image of its power plant. That is another reason why a modern power plant operator must organize his facility's operations with confident professionalism.

Process management issues necessitate falling back on the plant's technical documentation. Modern technical documentation is also computer-based these days and may be integrated into a given infrastructure. Control engineering data are a necessary basis for the proposed consulting part of this project. This consulting sub project will inspire the designs engineers and the shift management to develop new methods, new options and new processes for fast and reliable load ramps and stable conditions during minimum load operation. Another course of action in order to safeguard a reliable handling of the power plant processes is to pursue a strategy of increasing operating personnel assignment interchangeability. One and the same operator will be expected to run the steam generator as well as the turbo generator under full load conditions or challenging load ramps. At the same time, he also has to be capable of mastering certain facility and control engineering maintenance assignments. Ideally, some of the local operators will also be qualified for unit operations, revealing an emerging trend towards universally employable staff. This is another business aspect of the new and flexible energy market.

The future range of tasks of operating as well as local or maintenance crews is bound to expand, especially in connection with the employment of suitable software systems designed to assist the operating personnel's efforts. In addition, individual processes usually proceed very quickly so that crews can no longer follow events in real time. This, too, might cause a proficiency loss over time, especially if certain operating conditions that occur only very rarely or the new procedures needed for the new energy market in India have not been addressed regularly in the previous training. It is indispensable, however, that control crews are able to keep track of the new processes. This kind of skill can only be developed, preserved and enhanced through continued personnel training as proposed in this report.

2.3.3 Technical Staff

For this group it is necessary to learn about technical solutions required to expand the load and operating range of the plant. It is also most welcome when this staff is enabled to develop even more advanced solutions for problems like unsatisfactory load gradients, minimum load conditions, wear or fouling problems.

The technical staff group should be divided into two subgroups:

- Mechanical maintenance staff
- Electrical and automation staff

Joint training sessions are advisable and helpful, depending on the contents of the training modules.

2.3.4 Operations And Grid Coordinators And Maintenance Coordinators

This report recommends the establishment of service positions for operations and grid coordinators and maintenance coordinators. This new positions for the coordination of plant operations and the flexibility demands of the grid services are needed because dealing with the following topics directly related to flexibility demands professionally and methodically is essential:

- Maintenance and repair concepts
- Availability analyses and planning for flexible production of the plants
- Market price monitoring and evaluation
- Efficiency considerations for different load and production scenarios
- Technical feasibility of possible external requirements from the grid or load dispatcher with regard to flexibility scenarios
- Establishing, maintaining and fulfilling trade contacts
- Further development of grid ancillary products and other grid services
- Weather and production forecasts

This qualification programs are needed in order to train highly professional and qualified intermediate- level managers which are capable of combining their operational expertise with the new business know-how to a new “know how and know why standard” that seems to be the key factor for the current style of operations of power plants under flexible production conditions.

2.4 The Four Components Of Implementation Measures

The overall preparation concept for the staff of Indian fossil-fired power plants playing a major role in the evolution of a flexible energy market under the conditions of variable and intermittent power output employing renewable energy sources is subdivided into four components:

2.4.1 Training

- Preparation training
- Flexibility training (integrated simulator exercises employing compact classroom simulators)
- Simulator training using Indian power plant simulators
- Training on grid simulators, conducting emergency exercises for management personnel
- Competency training

2.4.2 Follow-up

Follow-up within three days after the completion of the measures, 4 - 6 weeks after training. Power plant-specific and conducted with the management of the respective power plant and selected participants.

2.4.3 Qualification And Competence Development Programs

- Recommendations for the internal promotion of individual participants
- Recommendations for specific or advanced training of individual participants
- Qualification Program for Classroom and simulator trainers (Train-the-Trainer courses)
- Qualification Program for company and network coordinators with final examination
- Qualification Program for maintenance coordinators with final examination

2.4.4 Follow-up

Consulting for the technical and organizational development of the power plants

- For further training and preparation measures on site
- For the qualification of the plant's systems and its technologies
- For the qualification of the control and automation technology employed
- For the organizational qualification of the plant management and the management regime

Flexibility-Training-Program “Operation Personnel“			
Types	Preparation Operation Training	Flexibility Operation Training	Simulator Training
Characteristics	• Refreshment training • Preparation for the participation in the Flexibility Training • Plant generic but specific technical contents • Design and operation of the “Home Plant” • Basic understanding of economic context with close relation to plant requirements	• Preparation for the participation in the Simulator Training • Broad technical understanding comprising various plant technologies • Enhanced knowledge of technical limits and options to cope with those limitations during flexible operation • Understanding of economic context with close relation to plant requirements • Basic knowledge of operating and maintenance procedures	• In-depth knowledge of operating and maintenance procedures • development of new operation procedures • Broad understanding comprising the complete scale of plant operation • Professional handling of malfunctions • Professional handling of high speed start up and shut down procedures and loads ramps • Optimization of cold, warm and hot start up procedures

Types	Preparation Operation Training	Flexibility Operation Training	Simulator Training
Characteristics		• optional: Classroom trainer for the Flexibility project (shift supervisor status or Engineer certificate required) trainer (Train-the-trainer training)	• Handling of outage conditions • Black start up procedures • Decision and control room staff management • Leadership training • Cultural change of operation competencies, gaining operative excellence • Learning to take proactive approaches operating the plant • Regularly virtual plant checks • optional: Simulator trainer (Train-the-trainer for Simulator training)
Target group	Operating personnel (local and control room)	Control room personnel, shift supervisors and shift engineers	control room shift groups
Achievement	Qualified Prep-op-certificate (compulsory for the Flexibility Training modules) (optional: recommendation for further promotion)	Qualified Flex-op-certificate (compulsory for the Simulator Training modules) (optional: recommendation for further promotion)	Sim-Flex-certificate (optional: recommendation for further promotion)
Certificate	oral and written tests	oral and written tests	practical test of plant operation employing the simulator practical test of shift group management during flexible operation as shift supervisor
Potential function	Local and control room operators	control room operators foreman or shift supervisor	shift supervisor, flexibility advisor for shift supervisors, operation and grid coordinator(*) or simulator trainer

Flexibility-Training-Program “Technical Personnel“

Types	Preparation Technical Training	Flexibility Technical Training
Characteristics	• Refreshment of know how • Preparation for the participation in the Flexibility Training • Plant generic but specific technical contents • Design and operation of the “Home Plant” concerning service and maintenance procedures • Basic understanding of economic context with close relation to maintenance requirements	• Broad technical understanding comprising various plant technologies • Enhanced knowledge of maintenance methods and strategies to cope with maintenance requirements during flexible operation • Enhanced understanding of economic context with close relation to plant and maintenance requirements • Basic knowledge of operating procedures • Broad understanding of economic context with close relation to maintenance requirements • optional: Classroom trainer for the Flexibility project (maintenance supervisor status or Engineer certificate required)
Target group	mechanical, electrical and automation maintenance or service staff (local and workshop)	mechanical, electrical and automation maintenance or service staff (local, workshop and management)

Types	Preparation Technical Training	Flexibility Technical Training
Achieve-ment	Qualified Prep-tech-certificate (compulsory for the Flexibility Training modules) (optional: recommendation for further promotion)	Qualified Flex-tech-certificate (optional: recommendation for further promotion)
Certificate	oral and written tests	oral and written tests
Potential function	Local and workshop service staff	service foreman, maintenance supervisor, maintenance coordinator(*)

(*) Qualification program with final oral and written qualified examination.

Flexibility-Training-Program "Management Personnel"		
Types	Classroom Workshop	Simulator Workshops
Characteristics	• Business methods for handling of technical and operational limitations for the participation of the "Home Plant" in the Flexibility program • Deep and wide understanding of economic context with close relation to the requirements of the flexible market • Operational and organizational strategies for tailor made plant structures: shift schedules, shift systems (4, 5, 6 shift systems), minimum number of control room staff, plant operation management for the production and maintenance, spare part management, workshop organization etc. • Broad understanding of grid requirements and load dispatcher tasks • Hazards of plant and grid outages, black start up procedures, auxiliary systems for black start up capabilities, grid rebuild procedures after outages	**Power plant simulator** • Operation procedures for quick start up, shut down, load ramps, limitation of minimum load • Management of fuel consumption and technical resources during times of high market prices of electrical power • Methodologies for the mitigation of the effects of malfunctions • Plant efficiency during minimum load conditions and load ramps • Risk management during plant operation **Power plant simulator** • Grid behavior under different load conditions (voltage, frequency, inductive and reactive power behavior) • Properties of dense city grids or long span transportation lines • Communication with local utility companies, load dispatchers or other plants • Grid rebuilt and set up procedures • emergency management during outage conditions of grid and/or plant
Target group	senior plant management, senior engineers	senior plant management, senior engineers
Achieve-ment	Certificate of attendance	Certificate of attendance
Potential function	promotion to a function on company level (senior manager, senior advisor)	promotion to a function on company level (senior manager for ancillary services, senior advisor for flexible operations on fleet level)

2.5 Training And Instruction Methodology

Successful participants in the proposed training courses will have access not only to comprehensive information from the handouts devised, but also to the professional instructors and their expert knowledge. Instruction must be conducted by seasoned engineers who pass on their expertise to participants.

The main objective is to achieve comprehensive training of all participants and thus places great emphasis on each individual trainee's progress. Some participants may take more time to absorb theoretical knowledge than others. In order to maintain the highest possible training standard for all participants, possible individual training requirements and proficiency deficits need to be identified early on. For that purpose, trainees will be quizzed on a regular basis as the main method to measure training progress. After establishing and analyzing the current training status, sub-standard participants will be given appropriate individual tutoring to help them catch up. This is the best way to improve a trainee's professional understanding of his new task at the power plant.

In order to offer participants as much practice-oriented learning as possible, employing a number of Indian power industry practitioners as expert instructors seems promising. German and Indian instructors should be jointly prepared for their assignments. With their substantial real-world experience, this group of instructors will bring the power plant to the classroom for the benefit of the trainees. In addition, sophisticated compact power plant simulators will be employed for exercises during training. Such simulator exercises will enable trainees to better understand the newly developed power plant processes.

In order to attract and to keep the participants' attention for a topic, it is important to get students involved in the classroom proceedings by having them work out some of the solutions and answers on their own. Instructors in these so-called “impulse program courses” attempt to accomplish that by utilizing a variety of media, among other things. In order to make sure that abstract data are thoroughly memorized, it must be taken into account that the visual share of memorization is approximately 80 percent. Teaching psychology also reveals that facts conveyed visually are remembered significantly better than those conveyed verbally. A varied and concise presentation is necessary. Excessive use of media, however, detracts from training contents and will be avoided. The group of instructors must therefore try out the chosen media in advance in order to familiarize themselves with the proper handling of such technology.

In addition to classroom training, simulator training sessions are very much needed in his project. For these operations training sessions, life-sized full-scope training simulators are needed. In Germany, such training simulators are available. Since those German simulators do not emulate the Indian power plants, however, it makes sense to employ the Indian training simulators available. As outlined above, it makes sense to establish a group of simulator instructors from both countries, too. This group of simulator trainers has to develop training sessions covering load and operation scenarios under the conditions of volatile production using renewable energy sources. The German simulator trainers should contribute their experience from similar training sessions for the German market while the Indian simulator trainers should share their experience from Indian simulator training and the specific qualities of Indian power plant staff. This composite group of simulator trainers should prepare for their duties in Germany together, employing German full-scope simulators and either adopt the German training procedure or develop new training procedures and scenarios for this project. The Indian simulator trainers will familiarize themselves with the German approach to simulator training that way. This method has been employed many times with great success.

2.5.1 Faculty Training For Indian Trainers

It is imperative that instructors be indoctrinated in relevant state-of-the-art technology. This applies particularly to the Indian plant personnel proposed for “Train the trainer” courses.

Instructor training for new Indian trainers having attended the training modules themselves and having been proposed for the “Train-the-trainer courses” should take place at the earliest possible time and may be conducted at independent advanced training in Germany or by German specialists.

On the one hand, the purpose of this promotion training measures for high potential employees will lie in the acquisition of confidence in the terminology and the application of new relevant technology. On the other hand, new training methods tailored to the specific conditions in India and for the demands of the new challenges for the Indian power plants and its employees must be worked out.

2.6 Training Objectives Recommended For This Project

Training for this project should focus on two important aspects:

- Conveying the technical know-how needed in order to achieve high plant availability, flexibility and economical operations capability for the new challenges of renewable energies.
- Meeting the requirements of future flexible operations of power plants by qualified personnel.

These objectives will be taken into account for the selection of training subjects and trainers in this project.

“Preparation Level Modules” will convey fundamentals in power plant technology and natural sciences in order to prepare the participants for the “Flexibility Level Modules”. These latter training modules comprise the behavior of plants for renewable energies, ancillary and auxiliary power plant installations, electrical installations, control engineering and especially the operation of minimum load conditions and highly flexible load changes with regard to business and environmental protection considerations.

In detail those “Flexibility Level Modules” will focus on the following aspects:

Dynamics

- High operational gradients (load change rate)
- Short ramp-up time for minimal and nominal load
- Short minimal stand-still time

Operational flexibility

- High number of start-ups and load cycle at reduced life-time consumption
- Low minimal load with high efficiency
- Uniform high-level efficiency-profile at a wide load range

Fuel flexibility

- High plant availability in spite of coal blending and imported coal
- Coal treatment technologies and plant modifications (e.g. combustion processes)

Simulator training on full-scope simulators should round out training as outlined before. Simulator training for Indian fossil-fired power plants for which full-scope simulators are available in India should cover the following topics:

- Startup, shutdown, and load change operations, fuel change
- Warm and hot startup, block unit breakdown, malfunctions diagnosis and correction
- Operation procedures to handle minimum load conditions
- Acquisition of new operating techniques for operations and malfunctions in
  - Steam generators and turbines
  - Generator and grid
  - Auxiliary and ancillary installations
- Training for special operating conditions from employing renewable energies.

In addition, simulator training on grid simulators is recommended for management staff and senior engineers. Such simulators are available in Germany, but should they also be available in India, they should be employed.

Beyond the teaching of specific technical skills, the “Flexibility Training Modules” also familiarize participants with the need to focus increasingly on subjects like management and business tasks.

Having attended all parts of the training and all applied training modules the participants must be able to answer the following questions concerning the flexible operation of the plant:

- Which components and systems are particularly limiting or critical and why?
- What are the procedural contexts for those limitations?
- How does the new operation (fast load changes, operating at minimum load) affect the processes in the plant (for example flue gas cleaning, feed water regulation)?
- What are the limiting factors for the operation under minimum load conditions?
- Which process parameters (temperatures, pressures, filling levels etc.) need to be monitored?
- What influence do the new operation procedures have on plant safety?

The contents of the training modules for all types should be designed exclusively and based on following selection criteria for the home plants of the participants:

- Power plant type (boiler, turbine, electrical and auxiliary systems)
- Power plant size
- Degree of automation and level of control and operating technology installed
- Age of power plant
- Design parameters

As part of this project, a "Module and Content Matrix" will be developed and employed for the plant- specific design of all training modules. Selected operation and design parameters will be used for the input side of this matrix as well as for the results of the assessments. Output will cover:

- Scope and duration of the modules for the different groups of participants
- Contents and objectives of the modules for the different groups of participants
- Methodology applied and contents of handouts
- Exercises employing compact classroom simulator

(Compact classroom power plant simulators are typically generic simulators. They can be used and operated in groups of two participants. They are a very powerful training media for theoretical classroom training. Compact classroom simulators are capable of showing operation conditions and sequences in a very realistic manner, having the size of a handheld computer. During the classroom training the instructor can define small exercises concerning theoretical training objectives and the participants can convert those theoretical training objectives into practical operation conditions using the classroom simulator. The participants will be able to follow the system reactions of a fossil fired plant on their table in the classroom. This will enforce the training efforts of the classroom trainers. The handheld simulators cannot substitute full scale control room based power plant simulators)

- Training employing the life-sized full-scope (Indian) simulators
- Scope and methods of learning and tests
- Customization of quality control
- Details for the documentation of the execution of the course

The operation and designs parameters used as input for the module and content matrix will be derived from:

- Input of the owner company of the corresponding plant
- General information available on the corresponding plant
- Assessment of the power plant personnel
- Answers to a "Questionnaire" sent to the management of the corresponding plant
- Input from the management of the corresponding plant
- A personal visit of a managing project member to the corresponding plant

The analysis of the "Questionnaire" and the use of the information selected from other topics mentioned above will be a procedure to be developed during the project in order to generate consistent results as input to the "Module and Content Matrix".

Remark: "Module and Content Matrix" and "Questionnaire" will be developed in detail during the project. This report shows simplified and standardized samples in order to describe the general usage of these important project assets.

The content of the training modules should be subdivided into the following groups and aspects:

- Management personnel (senior management, senior engineers)
  - For the management level, special training measures concerning the profitability of load ramps, extreme load conditions or short shutdown or startup procedures are recommended.
  - Emergency training under blackout conditions or the reestablishment of the grid is also recommended.
- Operating staff (shift supervisors, control room personnel, local operators):
  - Supervision, operation and regulation of the unit and its individual components in order to maintain given parameters (execution of schedules) while adhering to safety requirements and ascertaining optimum block unit modes of operation
  - Startup and shutdown procedures
  - Output changes: Operating personnel are required to implement load distribution directives in the integrated power grid, adhere to contractual electricity supply agreements, the generation of renewable energy etc.
  - Malfunctions, damage, and post-damage conditions management
  - Materials planning assignments (including fuel supply and disposal)
- Technical staff (mechanical service staff, electrical and automation staff):
  - Service (including control and operating technology)
  - Repairs, especially with regard to the market price of electrical energy
  - Inspections, also with regard to the market price of electrical energy
- Operation and grid coordinators and maintenance coordinators
  - As an important part of the project, it is recommended to create the positions of "Operation and grid coordinators" and "Maintenance coordinators" in every power plant involved in this project. The "Maintenance coordinators" should focus on new and tailor made strategies for the maintenance of their plants.

All samples for training modules, listed in chapter 5 of this report are to be understood as comprehensive training subject listings. The specific content and topics of the training modules will be compiled specifically according to the technology of the specific power plant. Only those power plant systems, auxiliary systems and operating procedures which are identified as relevant for this power plant and the operation of the plant in the overall context of the flexible feed-in and the expected availability of grid services on the basis of the "Questionnaire" will be addressed.

In principle, the training must and will be adapted to the following conditions:

- Design and operation of the specific power plant ("Questionnaire" and available data)
- Requirements based on the evaluation of the "Questionnaire"
- Requirements of the management of the power plant "Questionnaire"
- Composition and knowledge of the training classes (Adaption during the course.)
- Learning performance of the participants (Adaption during the course.)
- Planned scope of the module ("Module and Content Matrix")

2.7 Training Materials - Handouts

The quality of training materials issued to the participants and the validity of facts stated therein are essential to the effectiveness of the training measures in this project. Materials must be comprehensive, plant-specific, and scientifically sound. They should also lend themselves to encyclopedic purposes (with references to additional sources where applicable). These training materials will extend in part beyond the scope of the contents of training courses by providing the reader with in-depth information to round out the subject matter. Wording suits the needs and abilities of the respective target groups and will be observed. Leaflets containing i.e. case studies being distributed in the classroom can subsequently be tacked onto the training booklets. Training materials will be primarily practice-oriented and suitable for everyday use on the job. In some instances, they contain how-to checklists for certain specific situations.

It is important to set up a process for the development of handouts for the different power plants. This process involves a streamlined and efficient procedure to create the handouts for the different courses and plants with a high overall level of quality as described above.

In addition to establish training materials, the project partners should compile and develop materials suitable for multimedia and internet applications independently.

Linking the many advantages of multimedia and internet-based conveyance of information is essential to a forward-looking training concept, which should also be flexible enough to accommodate and implement future developments in this field.

2.8 Training Materials - Handouts

- Service group #0

  A power plant in this group is not involved in the handling of volatile und intermittent power generation from renewable energies because:

  - There is currently no need due to the plant's status in the grid
  - There is no reasonable possibility of participation due to the age of the plant and its technical systems
  - Participation in the flexibility program is unlikely (supply contract) due to the grid organization

- Service group #1

  A power plant in this group has only little involvement in the handling of volatile und intermittent power generation from renewable energies because:

  - Low current local demand due to insufficient capacity for regenerative energies in the respective grid area
  - Appropriate retrofitting measures are required due to the age of the plant and its technical systems
  - Subsequent participation in the flexibility program is likely due to the future grid organization

- Service group #2

  A power plant in this group is only moderately involved in the handling of volatile und intermittent power generation from renewable energies because:

  - An increase in the amount of installed capacity of regenerative energies in the respective grid area is expected
  - Only minor retrofitting measures are necessary and can be carried out easily due to the age of the plant and its technical systems
  - Participation in the flexibility program is likely and various ancillary grid services are being expected due to the future grid organization

- Service group #3

  A power plant in this group is earmarked for a leading role in the handling of volatile und intermittent power generation from renewable energies because:
  - Current demand already exists or is imminent due to the installed power ratio of regenerative energies in the grid
  - Retrofit measures are not necessary due to the age of the installation and its technical systems
  - Participation in the flexibility program, especially as leading power station for various ancillary grid services, is expected due to the future grid organization

General proposal for the design, the contents and the allocation of training modules to the four power plant service groups:

- Power plants of the service group #0
  - No training measures are currently recommended If so desired, counseling for the organizational and technical development of the plant (Fit for Future) is available.
- Power plants of the service group #1
  - Information sessions of about three days duration for these power plants are recommended:
    - without quality assurance (QA)
    - without learning tests and examinations
    - without competence management
    - with organizational and technical counseling (Lessons Learnt)
- Power plants of the service group #2

  Customized training program with consideration of the limitations of the plant's operating capabilities identified (see questionnaire evaluation):
    - possibly with specially selected modules, which deal with the restrictions identified
    - with analytical quality assurance (AQA in a PDCA cycle)
    - with learning tests and examinations (where applicable)
    - with competence management for the employees of the plant
    - with organizational and technical counseling (Lessons Learnt)
- Power plants of the service group #3

  Two-week full-scope customized course program (according to the course matrix):
    - possibly with additional specially selected modules, which deal with the restrictions identified
    - with analytical quality assurance (AQA in a PDCA cycle)
    - with learning tests and examinations (where applicable)
    - with competence management for the employees of the plant
    - with organizational and technical counseling (Lessons Learnt)

2.9 Learning Tests

Learning tests should be compulsory for all training measures in this project as they are typically an integral part of every training measure.

Within a process-oriented management system employing the PDCA (Plan, Do, Check, Act) cycle, learning tests are the check "C" in this PDCA system, an internationally introduced standard.

Applying the learning tests and the PDCA standard, the instructors are asked to check the test results versus the training objectives and make changes or additions to the training if necessary. The implementation of this standard for this project thus means the application of internationally recognized training standards and thus represents a "good practice" in the training and further development for the Indian power plant personnel.

Learning objectives are aimed at verifying the success of trainees, evaluating the quality of a training measure, and improving its efficiency.

Performing training is a service for the participants. Thus, a qualitative requirement is attached to the instructors to apply methodologic principles professionally. These principles include learning tests.

The trainees have to know what status they have achieved in the training, in which areas they have learned particularly well and which aspects need to be deepened.

By accepting feedback, the participants of training measures explain themselves responsible for the willingness to learn. The acceptance of a learning objective management is professional and shows a positive attitude of the training participants in the sense of quality management.

The instructors respond to this requirement by conducting learning tests a firmly anchored part of all training measures. In doing so, they correspond to the standards of a methodical and professional training, which is committed to the objectives of this project.

The project management responsible for the training concepts and measures is offered the opportunity to draw conclusions about the achievement of the objectives and the efficiency of the training measures. Type and extent can be determined by the nature and methodology of the learning tests.

As well as the contents of a training measure, learning tests have to be prepared, too. This includes the scheduling of time for their implementation, the selection of the method, the formulation of suitable questions or tasks and the associated sample solutions or answers. The tests have to be carried out individually; the individual results will be evaluated with regard to the achievement of the training group goals.

Undergoing learning tests, the participants learn whether and to what extent they have achieved the learning objectives. The results will show the participants and the instructors the learning advances and the necessities for the further work. The results serve as a confirmation for the trainee. To the instructors and the project management, they provide information of the success of the training methodology. The implementation of learning tests is thus an evaluation criterion for the quality of the whole training concept in this project and the single training measures conducted in remote locations all over India.

All tests and results should be commentated and online documented as a major factor in order to control the course of the project.

3. Quality management system and methodology

3.1 Conducting And Controlling

Conducting and controlling a project of this size and importance, the employment of a quality control system is unavoidable.

In this case an "Analytical Quality Management" (AQM) system is proposed. It refers to all those processes and procedures designed to ensure that the results of all locally gained data and information are consistent, comparable, and accurate within specified limits. Results submitted to the project management must be accurately described to avoid faulty interpretations. In training projects most of the data generated are qualitative type data. The importance of quantitative type data is not that relevant in training projects in order to evaluate the success of training measures with the exception of the learning test results. Since it is unlikely to gain quantitative type results from simulator training, it is necessary to develop tailor made assessments for simulator training measures based on the knowledge of operation procedures and the capability of the participants in order to operate the plant accordingly to those procedures. Because quality type data are employed most for controlling systems in training projects, the name AQM has been chosen.

Quality control in this project begins with the definition of training measures and objectives and proceeds with the reporting of data from the training runs and learning tests of the instructors from the different power plants. Initial control of the complete system can be achieved through a complete and thorough specification of training measures, objectives, methods, media and personnel. However, evaluation of the daily performance must be documented to ensure continual high standard of performance. The project management has to ensure that the information and data can be seen as precise and accurate. Systematic intermediate checks such as sitting in on lectures must be performed to establish the reproducibility of the training measures. The checks will help to certify that the training contents and methodology will be as planned and needed. By monitoring the accuracy and precision of the training program, the quality assurance program should increase confidence in the reliability of the reported training results.

The process controlling should be conducted by the project management and a number of commissionaires of Indian utility companies and/or the Excellence Enhancement Centers (ECC).

This kind of a continuous improvement process in the area of training requires efforts for preparation, follow-up and implementation of the training measures.

The preparation of the training measures on the project level includes an analysis of the existing and gained information as well as the knowledge concrete needs of the plant including a prioritization of the topics. This issue is to be appropriately linked with

- Technology of the plant (Questionnaire)
- Results of staff assessments
- Module and Content Matrix

At the end of a single training measure, sufficient time must be available to have a summary prepared by the participants themselves. The trainer(s) also need(s) to ask the group to provide feedback on whether and how the treatment of the measure will be helpful and useful for their new tasks and operation challenges.

A consistent logging of the training events is an essential pillar of the quality assurance process.

The evaluation must be carried out regularly in appropriate periods. The objective is to provide an overview of the current state of the project and the running or concluded training measures. At the same time, new topics or a further development of the assessments, the "Questionnaire" or the "Module and Content Matrix" must be evaluated and included in the training plan with appropriate priorities. Here, an important aspect is that the active support of the participants is also requested. This is intended to ensure that, on the one hand, the reference to the practice is maintained and, on the other hand, the potential within the team can also be used. These are essential prerequisites for creating and maintaining a continuous process.

3.2 Quality Cycle

It is proposed to employ the Plan-Do-Check-Act method, abbreviated PDCA method or PDCA cycle, as a classic method of quality development or assurance. The PDCA cycle describes the perpetual circulatory behavior of planning, acting, monitoring and reacting in order to achieve a higher level of quality in terms of efficiency as well as customer and employee satisfaction.

3.2.1 PDCA

PDCA is an iterative four-step management method used in this project for the control and continual improvement of the project and the training measures.

PLAN

Established objectives and processes necessarily will deliver results in accordance with the expected output. By establishing output expectations, the completeness and accuracy of the specification is also a part of the targeted improvement.

DO

During the implementation of the training plan and the execution of the training measures, data for charting and analysis will be collected for the following "CHECK" and "ACT" steps.

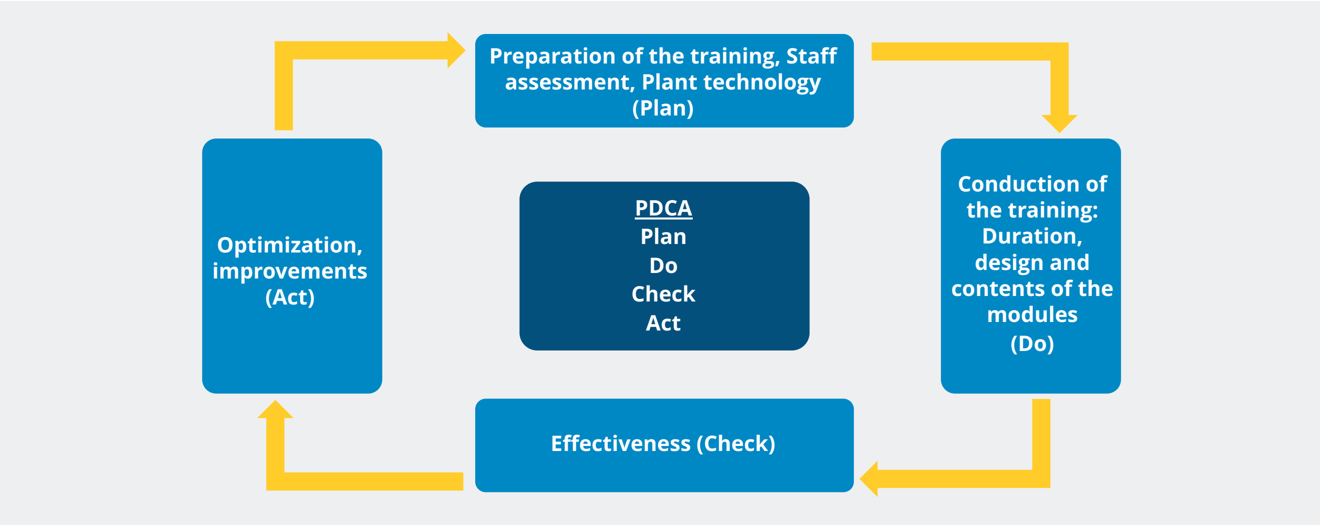
CHECK

Actual results (feedback from the training runs) will be studied and compared against the expected results (targets or training objectives from the "PLAN") to ascertain any differences. Deviation in implementation of the training will be looked for. It will be also looked for the appropriateness and completeness of the conducted training measures to enable a proper execution of following training measures. Charting data will make this much easier to see trends over several training runs. In order to convert the collected data into information, a complete documentation is needed.

ACT

If the CHECK will show, that the PLAN that was implemented in DO is an improvement to the prior standard (baseline), then it will become the new standard (baseline) for how the project organization should ACT going forward (new standards are enACTed). If the CHECK will show, that the PLAN that was implemented in DO is not an improvement, then the existing standard (baseline) will remain in place. In either case, if the CHECK will show something different than expected (whether better or worse), then there will be some more learning to be done in the project and that will suggest potential future PDCA cycles for other training runs.

Figure 2 PDCA Cycle



3.3 Three Stage Approach

The quality assurance system should be installed as a three stage process. It is assumed, that the whole project will be quite extensive. A numerus number of stakeholders will be involved.

In order to control this project from on the level of the project management, it is absolutely necessary do define SMART objectives for this project. This is to guarantee that all stakeholders will have the same understanding of the overall objectives. The management of these objectives starts with the process of defining specific objectives in a way, that the project management can convey the objectives to the stakeholders and project members, then deciding on how to achieve these objectives. This process also helps project members and stakeholders to see their accomplishments as they achieve the objectives. This is even more important, because the objectives will be employed as input data on the other levels of the project. SMART project objectives are:

- Specific – target a specific area for improvement.
- Measurable – quantify or at least suggest an indicator of progress.
- Achievable – state what results can realistically be achieved, given available resources.
- Responsible – specify who will do it.
- Time-related – specify when the result(s) can be achieved.

The 2nd level of the project will deal with the design and contents of training for different power plants and even more employees of those plants. Since all plants will operate in the same electrical grid and the operators in the power plants will have to cope with very same technical and commercial demands, it is necessary to achieve the same training objectives using possibly different ways of training employing different methods and media of training. Just common objectives can guarantee that this concept will work. The "Assessments" of the plant personnel, the technical "Questionnaire" for the management of the plants and the "Module and Content Matrix" will use the project objectives as input data. If the inputs to those three important means will be wrong or inaccurately, the output, the training measures will be insufficient or unsatisfying. This 2nd stage will be the "sustainability stage" of this project. It will be monitored and controlled how the training measures will work for the participants and how the participants will develop even beyond the end of the training measures. A three year phase of tracing time is proposed. Will there be a restart of the Indian power industry? Will employees start university studies or being promoted in their plants? Insufficient project objectives will show muddled results in this PDCA Cycle.

The 3rd level of the project are the training measures being conducted for various plants indifferent locations. It is inevitable to conduct a quality control PDCA Cycle in direct contact to the participants. This is the standard quality control process every training measure should employ. It is important to solve the “little issues” and the misunderstandings coming up from time to time in every course in every training measure, concerning speed of training, handout, rooms, seats and even meals. Those issues are an important part of every training course, since they open the minds of all participants for learning. Lifting this information to the 2nd stage, will help to optimize the next training sessions for other plants.

The three stages of the quality management are as described:

- 1st stage: controlling of the project
- 2nd stage: controlling of the design of the training measures and the development of the participants (professional education and promotion controlling)
- 3rd stage: controlling of the conduction of the training on site

Possible stakeholders:

- Government of India
- EEC
- GIZ/IGEF
- VGB Germany
- Indian Utility companies
- Indian Power Plant Training centers
- Management of the Indian power plants
- Training consultant
- Staff of Indian Power Plants
- Trainers

3.3.1 Project Controlling (Stage 1)

The 1st stage (PCDA-cycle #1) of the project controlling will ensure the quality of the process to develop the training objectives, the training measures. It will process the feedback from the conducted training measures. Following information will be dealt with, feedback from:

- The instructors
- Participants of the training (feedback sheets)
- The power plant management
- Emissaries of the project management observation of training measures)

If this feedback from the conducted training will show issues to be dealt with, the project team will immediately modify and optimize whatever issue is identified. The results gained on this stage will be employed to optimize succeeding training measures in other power plants in order to ensure a steady and continuous optimization of the training measures and its objectives.

3.3.2 Personnel Development Controlling (Stage 2)

The 2nd stage (PCDA-cycle #2) of the project controlling will evaluate and the personal development of the participants after the training and in the near future. The controlling process will start prior to the training of the participants, their professional history, their career and their position in the hierarchy of the plant. It will check and record how the participants will develop their career during the project and in the near future (i.e. 3 years of tracing). Will the participants be promoted in their plant, will they improve their competences or will they take part in other high level training measures or university studies? The results gained on this stage will generate an overview of the valorization of the project for the Indian Power Industry and the Indian professional training and education system in general.

3.3.3 Conduction and Performance Controlling (Stage 3)

The 3rd stage (PCDA-cycle #3) of the project controlling will ensure the quality of the conduction and the performance of the actual running training measures. It will process the firsthand feedback from the conducted training measures. Following information will be dealt with, firsthand feedback from:

- The instructors
- The participants of the training
- The power plant management
- Emissaries of the project management observations of training measures)

If this feedback from running training measures will show issues to be dealt with, the instructor will immediately modify and optimize whatever issue is identified. The results gained on this stage will be employed to optimize the running training measures in order to ensure the implementation of the defined training objectives or to modify of the originally training objectives in a close feedback with the project management. This 3rd stage of process controlling is particularly important during the 1st run of the training measures in order to optimize the following runs for one plant.

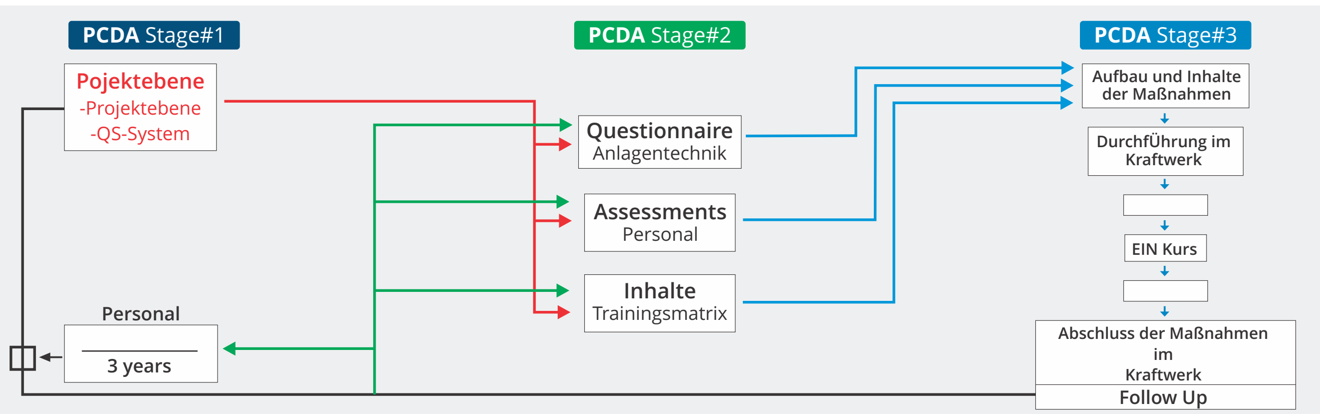
The information gained on the 1st and 2nd stage of the project controlling process will be also be employed to optimize the "Module and Content Matrix" and the "Questionnaire".

In order to complete this project controlling initiative, additional measures are needed after the conduction of the various measures:

- Feedback interviews with all stakeholders in a power plant
- Follow-up meetings with the participants and the plant management
- Preparation of a customized and detailed report concerning the training measures for each power plant
- Preparation of a customized and detailed report concerning the organizational and lessons learnt (Fit for Future)
- Review of the real capabilities of the plant systems and the operating personnel as late Follow-Up action moves

Because of the size of the project and the size of the Indian power system, it is recommended to organize all data online. This would bring the advantage that all participating groups, companies and stakeholder can access those data easily.

Figure 3 Quality Management



4. Training Modules

4.1 Preparation Modules

4.1.1 Boiler Design and Firing System

General training objectives:

The main objective of the "Preparation Modules" is to bring the participants to the current level of knowledge of the design, construction and plant engineering of their power plant. The participants will be prepared for the participation in the latter "Flexibility modules". The participants reactivate and deepen their knowledge about their own plant and its operation.

Specific training objectives:

This training module deals with the design and the operation of steam generators, including combustion, fuel processing and monitoring and safety devices. The participants learn about the principles of the operation of steam generators.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

Boiler Design

- Sub and super critical parameters
- Natural and forced circulation
- Once through

Heating Surfaces

- Counter flow; parallel flow
- Heat transfer (radiation; convection; conduction)
- Economiser; Evaporator, Reheater; Superheater
- Materials
- Surface cleaning

Operational modes

- Load ramps
- Minimum, part and low load
- Minimum load

Air Flue Gas system

- Air preheater (steam; flue gas)
- Fans (PA; ID; FD)

Solid Fuel (Coal)

- Composition (fuel; ash)
- Volatile Matters; water; ash content
- Slaging, fouling
- HGI (gindability)
- Heating value

Liquid and gaseous fuels

- Composition
- Heating value
- Viscosity, density

Combustion

- Flue gas composition
- Dew point (acid, water)
- NOx formation and environmental aspects
- Air excess
- Complete combustion

Mill

- Coal storage and mill feeding
- Drying, pulverizing
- Coal fineness and classifier
- Wear and maintenance

Burner

- Oil and coal firing
- Design features (Low Nox)
- Staged air principal
- Burner arrangement (corner, wall)
- Flame monitoring

Boiler efficiency

- Heat and mass balance
- Losses

4.1.2 Design and Operation

General training objectives:

The main objective of the "Preparation Modules" is to bring the participants to the current level of knowledge of the design, construction and plant engineering of their power plant. The participants will be prepared for the participation in the latter "Flexibility modules". The participants reactivate and deepen their knowledge about their own plant and its operation.

Specific training objectives:

This training module deals with the design and the operation of fossil fired power plants, including auxiliary, monitoring and safety systems. The participants learn about the principles of the construction and operation of fossil fired power plants.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

Components and systems

- Boiler
- Turbine

- Generator
- Water steam cycle
- Flue Gas system
- Cooling system
- Auxiliary systems
- Coal supply and ash discharge

Definitions

- Base, middle peak load
- Constant, sliding pressure
- Load regime, curve
- Load capability restriction
- Idle mode and black out
- Merit order
- Transmission, distribution
- Cold, warm, hot start

Ancillary services

- Frequency support
- Primary, secondary, tertiary control
- Black out management

4.1.3 Steam Turbine System

General training objectives:

The main objective of the "Preparation Modules" is to bring the participants to the current level of knowledge of the design, construction and plant engineering of their power plant. The participants will be prepared for the participation in the latter "Flexibility modules". The participants reactivate and deepen their knowledge about their own plant and its operation.

Specific training objectives:

This training module deals with the design and the operation of steam turbines, as well as the function of the auxiliary systems, automation systems, monitoring systems and protective devices of steam turbines.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

Turbine design

- Function and features
- Design parameters
- Components, valves and systems
- Materials

Water Steam Cycle

- Preheating (condensate, feedwater)
- Feedwater tank and pump
- Condensate pump

- Water treatment

Cooling system

- Condenser
- Cooling tower (wet, dry)
- Cooling water

Monitoring

- Pressure and temperature
- Vibration and revolution

Efficiency

- Parameters
- Design

4.1.4 Electrical Systems

General training objectives:

The main objective of the "Preparation Modules" is to bring the participants to the current level of knowledge of the design, construction and plant engineering of their power plant. The participants will be prepared for the participation in the latter "Flexibility modules". The participants reactivate and deepen their knowledge about their own plant and its operation.

Specific training objectives:

This training module deals with the design and the operation of electrical power plant systems. Behaviour of various electrical consumers in power plants and power transport in AC and three-phase power systems. Understanding and distinguishing of simple power plant-specific documentation of electrical systems. Structure, functions and operation of power grids. Behaviour of different circuit concepts in normal operation and in case of malfunctions. Design and functions of emergency power systems and monitoring during operation. Power plant electrical systems, switch gears, distribution systems for electrical energy and grid connections.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

- AC consumers and energy flow in AC circuits and distribution systems
  - Impedance
  - Reactance
  - Current and voltage profiles
  - Active, reactive, apparent power
  - Power factor
  - Pointer diagram for services
  - Compensation
  - Energy transport
- Frequency influence
  - Graphical representation of the current and voltage curves for three-phase current
    - Line diagram

    - Vector diagram
  - Symmetrical load
- Documentation of electrical installations
  - Circuit documents according to type of representation and intended use
  - Circuit diagrams
  - Terminal diagrams
  - Overview diagrams
  - Equipment identification
  - Typical switch gear designs for motors
- Unit supply block diagrams
  - Supply concepts
  - Switching options
  - Typical technical solutions
- Switch gears for single and two-directional drives
- Connection of power stations to the transmission network in different variants
- Block circuits with generator breaker
- Block circuits without generator breaker
- Busbar circuits
- Structure and operation of the self-service supply
  - Voltage levels
  - Parallel networks
  - Redundant networks
  - Short circuit behaviour
  - Short circuit effects
  - Voltage drops
  - Secured auxiliary system Voltage levels
  - Classification
  - Performance limits / short circuit
- Measures to safeguard auxiliary power system
  - External / secondary network supply
  - Automatic changeover systems
  - Quick changeover devices
  - Undervoltage bridges
  - Reconnection
    - Short-term power failure
    - Bus bar couplings
    - Selectivity

- Bus bar and Line failures
    - Island operation
    - Load trip
    - "Systematic procedure for operational malfunctions"
- Equipment, design and malfunction of electrical systems
    - Equipment
    - Rigidly grounded grids
    - Ground free networks
    - Compensated networks
    - Generator power lines
- Electric field
    - Capacitor
    - Insulation stress
    - Electric and magnetic field shieldings
- AC / DC networks of all voltage levels
    - Availability and clarification of malfunctions
- Importance and requirements for emergency power systems
    - Network interruptions during switchover
    - Voltage dips due to short circuits in the connected / remaining island network
    - Voltage levels
- Requirements of the power plant process
- Emergency power supplies with short-term interruption
- Uninterruptible power supplies
    - Rectifier
    - Batteries / Time Factor
    - Inverters / converters
    - Hazards in direct current distributions
- Lead-acid batteries (accumulators)
    - Mode of action of lead accumulators
    - Charging / discharging
    - Danger in battery rooms
    - Protective measures
    - Maintenance instructions
    - Emergency diesel sets
    - Monitoring
    - Test procedures
    - Synchronizatio
- Outage conditions
    - Diesel start under outage conditions
    - Operation under island conditions

    - Power recovery
- Grid reestablishment from island operation to voltage-free power lines
    - Monitoring, control and protection of steam turbines
        - Speed control (PI behavior)
        - Load operation with speed control (P-behavior, frequency control as the only feeder)
- Transformers
    - Relationship between number of turns and voltage
    - Magnetic field
    - Induction
    - (Re) magnetization
    - Eddy currents
- Loss sources of transformers
    - Power losses
    - Iron losses
    - Efficiency
- Dependencies
    - Idle operation
    - Load operation
    - Reduced cooling
- Dealing with the cooling systems of the transformers as a function of the cooling media
    - Start-up procedures
    - Operation / monitoring
    - Shut-down procedures
    - Malfunctions
- Mechanical monitoring of oil-insulated transformers and dry-transformers
    - Gas analysis
    - Oil analysis
    - Temperature monitoring
    - Buchholtz protection
    - Cooling circuits
- Electrical operating behaviour of transformers at idle and at different loads
    - Magnetization currents
    - Stray fields
    - Relative short-circuit voltages
    - Switching groups of three-phase transformers
    - Influence of reactive power

- Synchronization conditions of transformers
- Operational malfunctions of transformers
- Electrical and thermal faults in transformers and their effects
- Effects of overload
- Fire protection, sprinkler system (work safety)
- Gas collection Buchholz-protection
- Use of transformers which are switchable under load conditions
    - Switch assembly / switch installation
    - Areas of application
    - Reactive power adjustment
- Operation of current and voltage converters
- Operation and operating behaviour of asynchronous motors
    - Relationship between the rotating field, number of pairs, speed and slip
- Operational behaviour of the motor during acceleration and operation
    - Torque curve
    - Power consumption
    - Power factor
    - Voltage behaviour
    - Start up procedures
- Types and possible applications of speed adjustment / regulation
    - Two speeds
    - Frequency control
    - Slip control
- Monitoring and protection systems
    - Overload protection / short circuit protection
    - extended protective devices on high-voltage drives
        - Independent maximum current-time relay
        - Dependent maximum current-time relay
    - Ground Faults
    - Heavy and Smooth start up
    - Operational malfunctions and preventive measures
- Electrical and thermal / mechanical faults
    - Monitoring of the running motor
    - Overload tripping
    - Phase failure
    - Checking of the not running motor
- Effects of overload on aging
- Synchronous Generators
    - Practical effects of the induction during operation
    - Relationship between speed, number of poles, frequency, voltage and excitation

- Loss sources of generators
    - Current losses
    - Friction losses
    - Iron losses (eddy currents)
- Dependencies
    - Idle operation
    - Load operation
    - Reduced cooling
- Operation and malfunctions of cooling systems
- Handling cooling systems of generators as a function of the cooling medium
    - Start up / Filling
    - Operation / Monitoring
    - Shut down / Emptying
    - Standstill
    - Faults
- Cooling systems
    - Air cooling
    - H2 cooling
    - Water cooling
    - Operating values
    - Operating limits
    - Measures for
        - Lubrication
        - Operation monitoring and quality
        - Cooling
- Failures of coolers
- contamination of coolers
- Hot and cold gas temperatures
- Leakage detection
- Thermal classes
- Operation and disturbances of different excitation systems
    - Directly coupled DC motors
    - Static excitation devices
    - Brushless excitation with rotating diodes
- Brush fire and exchange
- Diodes failures
- Synchronization and grid connection
- Operation and electro-technical malfunctions of generators
    - Generator power diagram
    - Power adjustment
    - Voltage and frequency influence

    - Faults
    - Magnetic saturation
    - Controller malfunctions
- Grid operation
    - Turbine control and statics
    - Generator voltage controller / characteristic curves
    - Reactive power adjustment by means of the tap-changer
    - Island operation
    - Grid operation
    - Primary control, secondary control
    - Backlash of grid malfunctions
- Load trip to island operation
- Maintenance and inspection
    - Safety isolation
    - Inspection / Checking procedures
    - Start-up procedures
- Electrical plant protection: devices and their functions
- Protection objectives and structure of the electrical protection of the unit
    - Supply safety
    - Scope of safety
    - Selectivity
    - Plant protection
- Electrical / mechanical plant protection
    - Bimetallic relay
    - Independent maximum current-time relay
    - Dependent maximum current-time relay
    - Differential protection
    - Distance protection
    - 80% stator earthing protection
    - Under frequency protection
    - Protection against reverse power
    - Power jump protection
    - Rotor earthing protection

4.1.5 Renewable Energy Systems And Feed-in Behavior

General training objectives:

The main objective of the "Preparation Modules" is to bring the participants to the current level of knowledge of the design, construction and plant engineering of their power plant. The participants will be prepared for the participation in the latter "Flexibility modules". In this module the participants will learn about the grid-feed in behavior of different renewable energy plants in order to understand the demands of the grid control or the load dispatcher for the operation of their own plant under extreme load or ramping conditions.

Specific training objectives:

This training module deals with the design, the operation and the grid-feed in behavior of different renewable energy plants. The participants learn about the principles of the engineering of different renewable energy plants and the different causes for their volatile production of electrical energy.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

- Climate change and protection
- Greenhouse gas emissions
- Low carbon technologies
- Live cycle assessment (Carbon foot print)
    - Wind
        - On Offshore
        - Nest generation (high altitude)
    - Solar
        - Photovoltaics
        - Concentrated solar Power
    - Biomass
        - Terrefaction
        - Gasification
        - Conversion (Coal to BM)
        - Biogas
    - Smal hydro
- Feed-in conditions
- Specific characteristics
    - Volatibility
    - Predictability
    - Availability
- Power system Impacts
    - Efficiency
    - Environment
    - Life time
    - Grid stability
    - Generation cost

4.1.6 Electricity Market and Generation Cost

This module provides awareness about cost of electricity and influencing factors

Electricity Market in India and Germany

- Demand and Generation
- Role of Renewables (Tarif)
- Merit Order principal
- Emissions (development, impact)

Cost of electricity

- Fixe cost
  - CAPEX (equipment, project development, engineering, permit, site preparation)
  - Staff (OPEX)
  - Maintenance (fixe OPEX)
  - Others (fixe OPEX)
- Variable cost (OPEX)
  - Fuel (efficiency, load factor)
  - Start up and shut down
  - Disposal (Ash, Gypsum)
  - Water Supply and discharge
  - Life time consumption
  - Other OPEX (Aux steam)

Market for ancillary services

Comparison of generation options

4.2 Fexibility Modules

4.2.1 Boiler Operation

General training objectives:

The main objective of the "Flexibility Modules" is to prepare the participants for the new set of operation procedures in order to operate their plant under the new demands of the grid management under the volatile feed in of the renewable energy plants. The participants will be prepared and trained to meet the demands of a highly flexible and professional operation while respecting all rules of work and plant safety. One main objective of this module is to develop modified or new operation procedures and staff handling for the needs of professional power plant operation.

Specific training objectives:

This training module deals with the properties, auxiliary systems, safety and control systems of coal fired boilers based on once through and circulation design. The participants learn about state of the art operation procedures for minimum load operation, dynamic operation with high ramp rates and fast start-up and shut down procedures. This training is to be added with simulator training concerning all named operation tasks.

Prerequisite:

Knowledge and certificate of all Preparation Modules applied.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

- Minimum load operation (MLO)
  - Limiting systems, their components and limitations
    - Steam production and temperature behavior of Benson type boilers
    - Characteristics of supercritical benson type boilers
    - Economizer (minimum flow, pre-evaporation)
    - Evaporator (minimum flow, evaporation conditions)

    - Superheaters (steam temperatures and sprays)
      reheater (cooling, sprays, pressure)
    - Feedwater system, feedwater tank and pumps
    - Start-up vessel circulation pump and system (Once through)
    - Benson- and circulation conditions (mode change upwards and downwards)
- Combustion system
    - Oil Firing
        - Type and properties of oil, temperature control
        - Types and number of burners
        - Start up and shutdown procedures
        - Operation regime and safety regulations
        - Boiler trip conditions (boiler safety chain)
    - Coal Firing
        - Pulverizers (coal mills, types and number)
        - Milling process, coal properties
        - Wear out conditions, hydraulic pressure control for pulverization
        - Start up and shutdown of mills, inertization , risks of fire and explosion
        - Milling process under low air supply conditions (flow and temperatures)
        - Classifier behavior, temperature and temperature control
        - Operation regime and safety regulations (i.e. one mill operation)
        - Operation without supporting fuel
        - Boiler trip conditions (boiler safety chain)
- Process know-how
    - Water-steam-cycle, limiting systems or equipment because of design or previous operation regime
    - Turbine bypass system, safety bypass station(s), operation and safety functions
    - (reheater) safety valves
    - Feedwater tank, preheater system, bypass system, deaerator system
    - LP Preheater Bypass operation mode
    - HP Preheater Bypass operation mode
    - Condensate stop operation mode
    - Feedwater pumps, amount, design and system arrangement
    - Air and flue gas path
        - FD Fans, single or parallel operation, stalling limitations, pressure and stalling control
        - ID Fans, single or parallel operation, stalling limitations, stalling control
    - Flue gas cleaning (electrostatic precipitators, desulphurization treatment)
    - Critical process parameters for all topics (e.g. levels, temperature, flows, water composition)
    - Impacts on the plant safety for all topics
    - New O&M procedures (e.g. preservation of equipment, risk-based maintenance with changes of the inspections regime)
    - Economic background: minimum load operation vs. shut down

- Dynamic operation with high ramp rates (DO)
  - Limiting systems their components and limitations
  - Boiler stress management (piping system, headers, steam cyclones, valves, gate valves)
  - Combustion system, high ramp rates for mills and classifiers
  - Coal burners, design, operation modes and optimization of flow condtions
  - Emissions, CO-corrosion
  - Effects of high ramp load cycling – thermal fatigue resulting in higher life time consumption
  - Affected components and according mitigations strategies (e.g. high temperature components: superheaters, reheaters, economizer and air pre-heater(s), heat exchanging mechanism, shifting of high temperature spots, balance of steam flow and flus gas temperature
  - Design of the control system and strategies for handling and optimization
  - New O&M procedures (e.g. advanced condition monitoring linked with life time assessment, risk-based maintenance with changes inspections regimes)
  - Economic background: wear and tear vs. benefits of load following
- Fast start-up and shut down procedures (FS)
  - Limiting systems their components and limitations
  - Boiler conditions prior to startup (hot, intermediate, cold)
  - Typical startup procedures for hot, intermediate, cold conditions
  - Steam flow vs. pressure development during startup
  - Temperature development in the boiler (pipes inside and outside)
  - Operation of bypass station during startup
  - Fueling strategies (coal vs. oil, preparations procedures for mill start up processes, pre heating of mill and classifiers, preparation and readiness of feeders)
  - Smooth and rapid change of operation modes low load circulation to Benson mode
  - Behavior of the evaporator system, shifting of the evaporation zone in the evaporator system (h-p diagram, feedwater control system i.e. enthalpy control mechanism
  - Impacts on the plant safety, boiler safety chain
  - New O&M procedures (e.g. preservation measures, reduction of heat losses during stand-still)
  - Economic background: minimizing of startup costs, staff needed for startup procedures, fuel management and fuel consumption regime

4.2.2 One Mill Operation

This module describes the capability to run the power plant with one mill and elaborate the effects on emissions, instabilities and uneven parameters.

Objectives:

Operational limits Boiler

- Coal quality
- Flame stability
- Flue gas temperature
- Air balance
- Environmental aspects (e.g. NOx, CO)

- Monitoring (Flame, temperature, pressure)
- Uneven mass flow (flue gas, water, steam)
- Temperature and velocity profiles
- Erosion, vibration

Operational limits Boiler

- Feeding system
- Revolution
- Coal distribution
- Monitoring (vibration, wear, temperature, pressure)

Operational Limits Turbine

- Exhaust conditions
- Blade pressure
- Vibration monitoring
- Erosion

4.2.3 Electrical operations under extraordinary load and outage conditions

General training objectives:

The main objective of the "Flexibility Modules" is to prepare the participants for the new set of operation procedures in order to operate their plant under the new demands of the grid management under the volatile feed in of the renewable energy plants. The participants will be prepared and trained to meet the demands of a highly flexible and professional operation while respecting all rules of work and plant safety. One main objective of this module is to develop modified or new operation procedures and staff handling for the needs of professional power plant and grid operation.

Specific training objectives:

This training module deals with the properties of electrical plant systems, safety and control systems of turbines, generators, switch gears and extraordinary electrical operation modes. The participants learn about the handling of minimum power and island operation, grid rebuild procedures and the related issues. This training has to be supplemented and completed with simulator training employing all training objectives and themes named in this course program.

Prerequisite:

Knowledge and certificate of all Preparation Modules applied.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

- Design of the auxiliary electrical power system Construction of the 6kV (or higher) system with the different bars and transformers.
    - Concept of the 380V (or higher) system, the emergency power supply and the 220V DC system.
- Development of a methodology to recognize and handle specific operating modes (*0)
- Measures to be taken immediately when a blackout occurs.
    - Check the correct functioning of the emergency power supply (emergency power diesel, batteries). Maintenance of these systems.(*1)

    - Check the correct condition of the emergency units (emergency sealing flap, emergency lubrication flap)
    - Turn the turbine shaft if the shaft drive motor (crank) is not available. (*2)
- Test the emergency power supply in normal operating conditions. Sense and frequency (*3)
- Start of the unit from a blackout status
    - Step-by-step switching on the aux bars and starting the normal operating units. Priorities. Attention on circulation currents.(*4)
    - Only step-by-step acknowledgment of aggregates to avoid over-current switching due to automation.
    - Dealing with limitations in the performance required for start-up. (*5)
    - "Fall of technology" because of non-normal shut down of various plant systems. Opened valves, sprays and gate-valves, non-zero set points of controllers, non-vented and / or non-refeeded boilers. (*6)
- Training objective: Grid-Network re-setup development strategy
- Measures against excessive voltages due to capacitive grid properties and because of remagnetization of the power lines. (*7)
- Training the awareness that when the generator is started, it is not necessary to synchronize with the grid as usual.
- Impacts on the operation of the (first started) turbine. (*8)
- Operation of the steam generator when maintaining the "large island", keeping steam reserves (in the case of once-through steam generators with open bypasses) due to fluctuating load.
- Synchronization of a second generator. Impacts on the control mode. (one generator in speed control, one generator in power control)
- Voltage reactive-power management when maintaining island operation with one or more generators. Sudden tip over from the capacitive to inductive grid properties during power increase.(*9)
- Emergency measures if generators running during grid network re-installment are overloaded. (*10)
- Trip on Island Operation. (*11). Detecting the operating state by means of parameters such as speed, power and position of the different circuit breakers. Measures to be taken immediately in the area of cooling water, fuel mass flow, turbine speed control, steam supply of the feed water tank and auxiliary steam system, measures for controlling the ventilation of the steam turbine: Increase of the aux. power consumption, lowering of the reheater pressure. Starting of large electrical aggregates during island operation.
- Special options for the black start-up of combined cycle power plants. (*12)

Remarks to the numbers 0 to 12 referred in the above training program.

#0

Operating modes are e.g. interconnected power grids, large islands, island operation of a plant/unit, power outage, etc. There are often various procedures for special operation modes being used in different plants. It will be dangerous if the control room operator wrongly identifies the operating mode and employs the wrong procedure. Mostly followed by great damage or aggravation of operation conditions. This can be avoided by the consistent monitoring of all relevant circuit breakers.

#1

Training of “reflexes” to control and check voltages and currents and knowing and employing the right DCS Charts. There will be only less time available in the case of these problems. Furthermore, if the emergency Diesel generator cannot be operated for a long time, there may be thick liquid (maintenance) in the fuel oil tank. Also one must check whether the burst disc of the condenser is not broken. After the blackout, steam might exhausted by the steam turbine (the filling) and the cooling water pumps have tripped because of the outage.

#2

This has imperatively to be trained. This hand crank will be in a cabinet, which is often locked. It starts testing whether the staff knows where the key is, where the cabinet is, how the appliances are to being built together, and how they are ultimately to be used. Not turning the warm turbine will have catastrophic consequences.

#3

Examples: A broken battery that is not under load indicates voltage. It is only possible to check the voltage of a battery under load conditions and to see whether it is “OK” or broken. Management of fuel oil, test operation procedures etc.

#4

When the emergency units are in operation, there will be other priorities for the start-up sequence of other systems. The control room personnel must be able to estimate this tasks correctly. If bars are fed via two paths (because of false switching conditions), there may be circulating currents and overloading of certain transformers.

#5

Start-up procedures with one instead of two air-flue gas paths in order to save energy.

#6

Because of the power plant has not been shut down normally, many flaps, valves and gate valves may be still open. It will be dangerous if pumps will be started against open gate valves (or they are locked to start and nobody of the control room personnel knows why).

#7

Turn down of the voltage controller of the generator to 90% of U_{nom}. Set tap switch of the transformer to minimum. Starting of as much as possible of electrical aggregates (those aggregates are inductive consumers and compensate the capacitive reactive load) (once the main generator is in operation runs there will be no more power restrictions.)

#8

Many turbines automatically switch to power control mode after closing the power switches. Of course, it is necessary to remain in speed control mode. Also the temperature clearance conditions of the turbine must be good because the turbine has to be load as quickly as possible after switching to the grid

#9

An unloaded grid has capacitive properties, which together with the magnetization, can lead to high voltages when switching the generator to the grid. When increasing the load of the generator, however, the grid will get very quickly inductive properties (due to the reactance of the lines, which will only show up if transport of power is present), which can lead to trips due to low voltage.

#10

It is optional to reduce the voltage of the grid in order to reduce having too little generation capacity. It is known, that P (MW) = U2 / R. (U is mains voltage). In this way it is possible to reduce the load of the grid for some time

#11

Since it can go something wrong during the reestablishment of the grid conditions. The units/plants have to intercept on island operation. The reestablishment of the grid will become much easier then. The control room personnel must also be familiar with this mode of operation and these specific items.

#12

For CCPP plants with two gas turbines one of them should supply the aux. electrical system of the plant and the other one should the rebuild the grid conditions. If the grid will trip again, this is more safe. The second turbine set can synchronized later to employ also the performance of the turbine set for the aux. electrical system. The steam turbine set could be switched to the grid, too, but it is important to be careful that the steamturbine generator does not force the gas turbine sets under minimum load conditions.

4.2.4 Maintenance Procedures and Strategies

General training objectives:

The main objective of the "Flexibility Modules" is to prepare the participants for the new set of plant management procedures in order to operate and maintain their plant under the new demands of the grid management under the volatile feed in of the renewable energy plants. The participants will be prepared and trained to meet the demands of highly flexible and professional maintenance procedures while respecting all rules of work and plant safety. The main objective of this module is to develop modified or new maintenance procedures and strategies for the needs of professional power plant operation.

Specific training objectives:

This training module deals with the objectives of plant operations and maintenance, as well as the organization of maintenance. The participants learn about state of the art and intelligent management of these tasks.

Prerequisite:

Knowledge and certificate of all Preparation Modules applied.

Certificate:

This module includes learning tests and concludes with a qualified certificate of participation.

Content:

Data and information for operations management and maintenance

- Data and information
    - process data and plant data
    - required data for operations management and maintenance
    - plant description
    - Function and equipment
    - Parts list
    - Structuring
    - Service-life- influencing measures
    - Reliable and long-life operations management

    - Wear-reducing measures
    - Wear-monitoring measures
    - Measures for eliminating degradation
- Degradation of plant and equipment
    - degradation
    - Thermal fatigue
    - Effects of cycling – thermal fatigue resulting in higher life time consumption
    - Wear and wear damage
    - Failure distribution
    - General handling method
    - Reliability of components
    - Availability
- Operations
    - Data and information for operation management
    - Time and event based data
    - Mean values
    - Data storage
    - Balancing, plausibility, validation
    - Performance data for process controlling
    - Heat transfer, Temperature differences and degree of efficiency
    - Conclusions
- Diagnosis and maintenance
    - Importance of maintenance and Maintenance costs
    - Maintenance strategies (breakdown, time-based, condition based, risk based and know-how based)
    - Maintenance or replacement
    - Optimization principles for flexible operations regimes
    - Working steps
    - Necessity of diagnosis
    - Condition diagnosis
- Organization of maintenance
    - Large and small scale maintenance
    - Continuous maintenance
    - Strategy development for availability based maintenance
    - Production based maintenance
    - Maintenance schedules for availability of the plant under the flexible operations regime
- Evaluation methods
    - Data and information for the production process
    - Plant Condition
    - Damage identification

- Resource planning and progressing
- Future oriented cost strategies
- According mitigation strategies for worn out components or components under thermal-fatigue
- Estimate economic efficiency
- Flexible step by step concept
    - Energy management
    - Flexible market management
    - Replace management

4.3 Simulator Modules

General training objectives:

A simulator training module contains operation of power plants under the regime of volatile feed in of renewable energy plants.

Simulator training is an essential part of the proposed training measures in this report. Decades of worldwide experience in this field prove that the more simulator training adapts to the specific requirements of a training project the more effective it is.

Therefore it is recommended to create a module pool for this project that contains recognized and especially designed building blocks for the compilation of individualized simulator courses for the different groups of participants coming from different power plants. The innovation of these modules has to be their compartmentalization, which means they can be customized to defined target groups and training objectives.

Modularized simulator training will benefit this project since a wide range of target groups according to the general training concept proposed, will have to be trained.

Depending on the target group and the course's objectives, modules will focus on four areas and compiled individually for specific simulator training course programs in this project.

The first three areas of this module pool cover technical topics, the fourth one interdisciplinary skills.

The module pool has to be designed as part of this project to adapt the simulator training to the specific advanced training needs of the different groups of this project. It should feature four areas of training:

- Process engineering
- Electrotechnology
- Control engineering
- lnterdisciplinary skills

Compartmentalizing of these areas of training with regard to the target groups and training objectives defined in the “Module and Content Matrix” have to include:

- Pre-existing knowledge and skill level of trainee(s)
- Identification of specific and interdisciplinary skills to be enhanced by training
- Matching Indian simulators to existing power plants

The compilation of the training courses will define not only the training contents, but also the duration, the type of simulator required and the training objectives defined by the project and the “Module and Contents Matrix”.

Specific training objectives:

This training module deals with the properties, auxiliary systems, safety and control systems of supercritical coal fired boilers. The participants learn about state of the art operation procedures for minimum load operation, dynamic operation with high ramp rates and fast start-up and shut down procedures. This training is to be added with simulator training concerning all named operation tasks.

Types of simulators:

The simulation scope describes the usability scope of a simulator for training. The largest possible scope of simulation is called "full-scope". Simulators that completely describe the real plant to be replicated are referred to as full-scope simulators. In general, the full-scope simulators emulate the technical system to which they refer 1:1. The display charts on the control room screens are exactly replicated. Power plant simulators, however, the full-scope simulators mainly, refer to the dynamic representation of the processes on the screens and the operation of the entire system.

In the case of a partial simulator (so-called "part-task simulator"), the system to which the simulator refers is also exactly emulated, but only in cut-outs or partial areas from the real plant in order, for example, to only essential or special tasks. Possible influences of the not simulated systems of the plant are not taken into account. This must be evaluated in the results.

"Basic-Principles-Simulators" illustrate general concepts, functions and the technical processes of the plant, which can be found in every power plant.

“Generic simulators” are particularly useful when it comes to train a basic understanding. They are usually composed of basic principles simulators and part-task simulators. For trainees coming from different type of power plant, a 1:1 simulator is considered to be a “generic simulator”.

The simulation quality of individual simulated power plant systems is an indication of the qualitative degree of modelling. The highest claim to reproducing reality is achieved by reproducing reality as precisely as possible (so-called "high-fidelity simulator"). In the case of smaller requirements, often a simplified simulation is be defined by using simple algorithms and logic simulation with respect to the simulation scope and quality.

Depending of the type and quality of simulators being available for different Indian power plants the modules and exercises have to be adapted. In general quite every type of training simulator can be employed for professional training measures, since training simulators typically have some important functions:

- Overrides for
    - All values
    - Controller set points
    - Environmental conditions
    - Fuel properties
    - Capabilities of the plant systems
    - Capacities of the plant systems
    - All indications
    - All automation procedures
    - All trip conditions
- Malfunctions
- Nor wear out problems
- Reset to start conditions of the exercise
- Indefinitely rehearsal options

Never the less other available simulators could be employed for specific exercises. Finally the design of the simulator training procedures and the exercises as well as the professionality of the simulator trainer are substantial for the success of a training measure.

Prerequisite:

Knowledge and certificate of all Preparation Modules and all Flexibility Modules applied.

Certificate:

These modules include performance tests of plant operation and conclude with a qualified Sim-Flex-certificate of participation.

Content:

The modules listed below are to be regarded as examples and suggestions for this project. Because of this modularized course concept, suitable modules from the four areas available may be combined in one simulator training course in any way that meets the individual requirements of the different plants.

Process Engineering Section

- Efficiency optimization of the power plant
- Fast start up and shut down procedures
- Identification of limiting systems, processes and components
- Exercises: Anticipation of critical process parameters for fast ramp conditions and minimum load conditions (e.g. levels, temperature, flows, water composition)
- Development and exercises of new operation procedures (e.g. 1-2-mill operation, preservation of equipment, operation without supporting fuel, risk-based maintenance with changed inspections regimes)
- Operation of the power plant during load ramps
- Operation of the power plant under minimum load conditions
- Fuel handling and professional operation of the combustion system
- Exercises: Possible operation procedures beyond the known limits of operation
- Exercises: Effects of flexible operation on the efficiency of the power plant
- Exercises: Costs of flexible operation procedures
- Exercises: Anticipation of wear outs
- Operation of boiler and turbine during island operation of the plant
- Effects of cycling – thermal fatigue resulting in higher life time consumption
- Affected components and according mitigations strategies (e.g. high temperature components: superheater, reheater; LP-part of the turbine; economizer and air preheater)
- How to manage malfunctions safely
- Unit control with primary, secondary, and tertiary frequency control, modified and natural even-pressure gradient.
- Impacts of operation procedures on the plant safety

Electrotechnology Section

- Primary, secondary and tertiary load- and frequency control
- Functionality of voltage control under different modes of operation of the power plants und different grid conditions
- Grid disturbance impact on plant operations
- Generator operations and grid behavior as well as voltage control

- Affected components and according mitigations strategies for generator windings and insulation
- Drop-off to Station supply/isolated operations-running in station supply/isolated operations mode-grid control strategies
- Post-blackout plant startup sequences
- Reestablishment of the electrical grid after black out conditions

Control Engineering Section

- How to handle plant operations professionally employing all features of the control system and technology installed
- How to handle new control features, methods or strategies
- How to develop new control features needed for the flexible operation
- professional navigation throughout the control system
- professional malfunction analysis in function diagrams or charts

Since the new challenges for the Indian power industry mandate not only technical, but also a great many interdisciplinary skills that should also be developed and enhanced in the training process, such as:

- How to give unequivocal orders and feedback
- How to gather and evaluate relevant information and make decisions during stressful operating conditions during ramps or minimum load conditions or malfunctions
- How to paraphrase

Interdisciplinary Skills Section

- Effective teamwork during a shift (team and decision-making behavior)
- Communication training (how to gather and evaluate relevant information during malfunctions, how to make decisions, give unequivocal orders and feedback)
- Efficient and appropriate team management during a shift
- Identifying the four safety levels in power plants, malfunction review and analysis
- Process optimization during shift changeover
- Decision making in a group (e.g. according to FORDEC)
- Economic exercises: Minimum load operation vs. shut down

4.4 Competency Modules

4.4.1 Competency Modules

General training objectives:

The main objective of the "Competence Modules" is to train senior staff for management tasks in their field of business for the new set of plant management procedures in order to operate and maintain their plant under the new demands of the grid management under the volatile feed in of the renewable energy plants. The participants will be trained accordingly with a unique curriculum to meet the demands of highly flexible and professional maintenance procedures while managing all maintenance tasks and controlling all rules of work and plant safety. The main objective of this module is to set up a new kind of maintenance procedures and strategies for the needs of professional power plant operation.

Prerequisite:

Knowledge and certificate of the “Flexibility Module Maintenance”.

Certificate:

This module includes learning tests and concludes with an oral and written examination to receive a certificate of competence.

Curriculum:

The contents of the "Flexibility Module "Maintenance" will be accentuated during this course.

Data and information for operations management and maintenance

- Data and information
    - Documentation
    - Service-life-Influencing measures
    - Reliability and Long-life Operations management
- Reliability an evaluation of failure behavior
    - Failure behavior
    - Failure probability and density
    - Mean service life
    - Availability
    - Reliability of supply and availability
- Operations
    - Stationarity
    - Steady state condition
    - Performance parameters for process controlling
    - Optimization of fuel efficiency
    - Optimization of operation procedures for wear out minimization and plant efficiency
    - Optimization of operation procedures for fast start up and shut down conditions
    - Optimization of operation procedures for pulverizes and coal burners (air flow ratios)
    - Identification of critical systems
    - Optimization of maintenance procedures and schedules for flexible operation of the plant
    - Optimization of maintenance procedures for high speed ramping
- Diagnosis and maintenance
    - Documentation of maintenance efficiency
    - Development of tailor-made maintenance strategies for the plant
    - Implementing new diagnosis systems
- Organization of maintenance
    - Generation of maintenance orders
    - Quality management for maintenance jobs
    - Definition of production based maintenance schedules
- Maintenance and plant controlling
    - Planning of resources
    - Optimization of maintenance measures
    - Planning of maintenance measures
    - Planning of unit overhaul measures
    - Development of a work permit system fitting the needs of the plant

- Networking with operations department and plant management
- Networking with other plants of the company
- Exchange of spare parts
- Development of mitigation strategies for flexible operations conditions
- Development of risk-based maintenance with changes in inspections regimes
- Optimization of economic efficiency
- Monitoring and documentation of life time consumption
- Consultancy for the operations department and the plant management

4.4.2 Grid Coordination

General training objectives:

The main objective of the "Competence Modules" is to train senior staff for management tasks in their field of business for the new set of plant management procedures in order to operate and maintain their plant under the new demands of the grid management under the volatile feed in of the renewable energy plants. The participants will be trained accordingly with a unique curriculum to meet the demands of highly flexible and professional maintenance procedures while managing all maintenance tasks and controlling all rules of work and plant safety. The main objective of this module is to set up a new kind of maintenance procedures and strategies for the needs of professional power plant operation.

Prerequisite:

Knowledge and certificate of the “Flexibility Module Maintenance”.

Certificate:

This module includes learning tests and concludes with an oral and written examination to receive a certificate of competence.

Curriculum:

The contents of the “Flexibility Modules “Boiler, Turbine and Electro technology” will be accentuated during this course.

- Plant operation
  - Optimization (efficiency, costs, profits, schedules, personnel)
  - Optimization (technically, lifetime consumption, operational safety)
  - Optimization (operations of units, plants and fleet, external units)
- Operation of electrical plant systems
  - Generators (functions, auxiliary systems, operation conditions, operation behavior, island operation, synchronization, load and voltage control, grid connection, switches, safety systems, trip conditions etc.)
  - Design and construction of the station service, switch gears and stations, circuit diagrams, electrical motors, motor safety systems, trip conditions, island operation, emergency supply systems
- Network grid operation
  - System interconnection
  - Interconnected network grid (architecture and operation conditions)
  - Grid malfunctions and failures, reestablishment after blackout
  - Technical burdens of the network grid for the power plants
  - Consumer burdens to the network grid

- Ancillary services
  - Scheduling and dispatch
  - Reactive power and voltage control
  - Loss compensation
  - Load following
  - System protection
  - Energy imbalance
  - Consumer burdens to the network grid
- Control strategies
  - Optimization and quality management of control systems and strategies
  - Development of new operation procedures derived from control strategies
  - Development of new control strategies for flexible operation conditions (minimum load, fast ramping operations, trip and safety conditions of the combustion system (i.e one or 2 mill operation)
- Efficiency management
  - Minimum load operation vs. shut down
  - Optimization of maintaining hot shut down conditions during downtime of the plant
  - Optimization of start up procedures
    - Fuel consumption
    - Maintaining pressures and temperatures
    - Professional operation of boiler circulation system and turbine bypass system during start up and shutdown procedures
    - Oil burner and pulverizer operation, start up and shut down sequences
- Energy management
  - Power plant being an asset of the company
  - Wear and tear vs. benefits of load following
  - Analysis of energy selling and/or supply contracts
  - Calculation of fuel costs vs. electrical production
  - Systems and software for energy management
  - Networking in energy efficiency groups (company, associations, other stakeholders)
  - Energy audits and auditing
- Energy trading market and trading conditions
  - Liberalized energy market
  - Costs
  - Prices
  - Professional energy trading
  - Full cost accounting
  - Part costs accounting
  - profits margins
  - Business indicators
  - Tasks of the controlling

    - Decision competences
    - Business forecasts
    - Price forecasts
    - Energy consumption forecasts
    - Weather forecasts
    - Strategies for plant operations concerning forecasts
- Legislature of power plant operation and renewable energies operation
    - Laws and rules
    - Legal conditions for the operation of fossil fired power plants
    - Legal basics of contracts
    - Practical handling of legal issues concerning the operation of fossil fired power plants
    - Systems and software for energy management
    - Work safety and work permit organization
    - Maintenance and service contracts
- Renewable Energies
    - Basic knowledge
    - Design of typical plants
    - Operation conditions

4.4.3 Train The Trainer

The competence module prepares systematically for the activity as lecturer and trainer. At first, the participants are familiarized with the requirements of the coach's role and then deal with the basics of learning. Participants learn how to plan and implement lessons, and learn how to select and prepare contents to suit their objectives and target groups. Based on this, moderation techniques and criteria for the selection and use of adequately supported media are developed in order to transport learning contents effectively.

An additional focus is the control of group dynamics processes. The participants learn to work with groups, to guide them and to motivate them to solve conflicts in the classroom and to deal appropriately with interferers. Furthermore, the participants are concerned with strategies to analyze the training needs of individuals and teams in organizations. Finally, the participants will also learn about techniques and methods of quality assurance and learn about the opportunities of education control.

The module includes two deepening practical exercises in which, under the guidance of professional trainers and in exchange with other participants, the substance is deepened and expanded. Practical project work will also be conceived and presented during these practical exercises.

The contents of the course are intended for all those who are already engaged in further education and training in companies and who wish to further qualify.

Prerequisite:

Participants of the training modules having received the recommendation of attending the Train-the-Trainer program because of their learning and teaching abilities discovered in the project.

Certificate:

This module includes learning tests and concludes with an oral and written examination and a practical exercise to receive a certificate of competence.

Curriculum:

- Fundamentals of training
- Work as a trainer
- Fundamentals of learning
- Role of motivation
- Preparation, execution and completion of seminars
- Method selection and switching techniques
- Control of group processes
- Planning and control

4.4.4 Instruct The Trainer

The competence module prepares systematically for the activity as lecturer and trainer in this project. The main focus is, to familiarize the participants with the technical contents of the Preparation and Flexibility Modules of this project as well as the technical background of and for the flexible operation of Indian fossil fired power plants.

This module will be available in five characteristics:

- Boiler and combustion technology
- Turbine and auxiliary systems technology
- Electro technology
- Control engineering
- Maintenance for efficient and flexible operation

The participants will also learn how to develop and plan training modules for additional power plants and to widen the knowledge base of this project. Based on this, project mechanisms and procedures will be taught, too, in order to prepare the participants for the further collaboration in this project.
The module includes also some training exercises employing power plant simulators in which, under the guidance and in close cooperation with experienced trainers. The participants will also be work as trainers in this module in order to input their needed knowledge about Indian management and operation procedures and to prove their new gained knowledge.
The attendance of multiple characteristics of this module is optional. The contents of the course are intended for all those who have joined or will join the "Train the trainer" Competence Module.

Prerequisite:

Engineers of the Indian stakeholders of this project being chosen to work as trainers in this project or participants of the training modules having received the recommendation of attending the Train-the-Trainer program because of their learning and teaching abilities discovered in the project.

Certificate:

This module includes learning tests and concludes with an oral and written examination and a practical planning of a new course module to receive a certificate of competence.

Curriculum Overview

- Technical background of the data pool for the challenges of flexible operation
- Summarized and deepened contents of the Preparation and Flexibility modules of this project
- Know why vs. know how

- Execution of course modules in at least one of the five characteristics
- Design of handouts for technical training
- Selection of technical objectives for new courses
- Preparation of training methods and media for technical courses
- Preparation of technical documentation
- Development and planning of new training modules
- Project mechanisms and procedures
- Quality management and assurance of course modules in this project
- Analysis of “Questionnaires” of this project
- Mediation of “Follow Up Events”
- Assessment procedures for power plant personnel in this project

5. Recommendations, next Steps and way forward

Recommendations

- Categorization of existing and new power plants
    - Efficiency and age
    - Flexibility potential (automation, design)
    - Power output
- Set up of
    - Pilot training program under the leadership of one Indian Institution (Hub)
    - Assessment and nomination process of participants
    - Review and evaluation process
    - Technical evaluation of simulator center in India
- Linkage to current flexibility project (VGB)
- Definition of plant specific scope of training in the pilot phase in a workshop
- Roll out for utilities in India

Next Steps

- Approval and design of new pilot project phase (e.g. Train/Instruct the Trainer)
- Kick off and definition of scope of training
- Preparation of training
- Location of pilot training (Germany)
    - Usage of Simulator and lab facilities
    - Study tours
    - Covering of a wide range of topics
    - Extensive knowledge transfer and sharing
- Fixing the training duration (e.g. 3 to 4 weeks)
- Number of participants (8 – 10)
- Nomination of participants (professionals and potentials)

Way Forward

- Execution of training
- Review and lessons learnt
- Start of roll out process