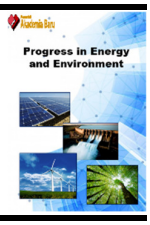
Penerbit Akademia Baru

Progress in Energy and Environment

Journal homepage: http://www.akademiabaru.com/progee.html
ISSN: 2600-7762



Comparative Review of Commissioning Procedures w.r.t Nuclear and Conventional Power Plant

Open Access

Muhammad Adil Khattak[1,*], Muhammad Arif Fadhlillah Abdul Manaf[1], Afiq Danial Abd Rasid[1], Nur Athirah Nordin[1], Lailatul Fitriyah Ahmad Shafii[1]

[1] Department of Nuclear Engineering, Faculty of Chemical and Energy Engineering Universiti Teknologi Malaysia, 81310 Skudai Johor, Malaysia

ARTICLE INFO

Article history:
Received 5 February 2018
Received in revised form 4 April 2018
Accepted 2 May 2018
Available online 13 May 2018

ABSTRACT

Commissioning is the process in which an equipment, facility, or plant is tested and verified. The verification and testing of all the components and systems must align with the design objectives and safety specifications.This paper reviews the comparative of commissioning in general nuclear power plant and conventional power plant. This paper's prior focus is to explain the commissioning of nuclear power plant and other common power plant while highlighting the importance of licensing and testing guideline during the commissioning in accordance to plant safety. In addition, the comparative of licensing and testing guideline is also reviewed. Apart from that, the summarization of commissioning that is classified into commissioning preparation, execution and documentation & handover to the operation is discussed. Moreover the roles and responsibilities of personnel in supervising the commissioning process to ensure the activities are run smoothly are simplified, the interactions and the main recommendations concerning the commissioning-related events. Furthermore, a general review on the organization development, feasibility studies, site selection, commissioning planning & scheduling, and construction phase is done.

Keywords:
Commissioning, nuclear power plant, , conventional power plant, licensing, testing

1. Commissioning

The general definition for commissioning is the process where an equipment, power plant, or any type of facility is tested and verified [1]. The verification and testing of all the components and systems must align with the design objectives and safety specifications. These three can be said to have almost the same meaning, where these terminology is used frequently in the engineering field [2-4]. The meaning of erection is basically the manufacturing end of a plant, where installation is setting up a plant to where it is to be used. The last but not least is commissioning that means making an overall examination of the plant installed [5-7].

* * *E-mail address: mr_kohatian@hotmail.com*

1.1 Activities of Commissioning

The commissioning process can be partitioned into several activities that consist of three main parts. These activities comprise of the commissioning preparation, execution and the documentation where it is handed to the operating agency [8-10]. Before any project takes place, the most crucial element needed is the preparation phase. This phase includes the preparatory work that shall include the activities for commissioning before the start-up process [11-14]. These activities comprises of the development of the commissioning organization, that is the community set-up and the human resources that is involved in their designated departments. Whether it be an engineering-based departments (mechanical, electrical, civil, control and instrumentation) or regulatory-based departments (safety, design basis, licensing) [15-17].The next activity is the development of system breakdown where all the systems within the commissioning process is evaluated and constructed for the breakdowns to be executed smoothly by the department's set-up [18-20]. The activity that follows is the packages definition where all of the breakdown packages is well defined in order to establish fabrication/installation priorities. Commissioning schedules is indeed one of the important preparatory work which pictures the project timeline and milestones that is needed to be covered within a certain amount of time [18-23] . Then there is the commissioning budget that includes spare parts for redundant purposes. This budget allows the commissioning project manager to allocate the budget to all the departments and procedures needed during the commissioning process. The commissioning preparation check record is also prepare before-hand. The status and readiness for any power plant for the commissioning process can be presented through a commissioning checklist that gives a list of in-depth details of a system [24-26].

The main focus in commissioning any power plant is the execution process according to the guidelines of a detailed procedure description. We first start off with the main objective of a power system commissioning procedure, which is to account and verify all the equipment in order to fulfil the design criteria for operation. This equipment must also achieve all the guaranteed safety requirements laid out by the safety authorities. The commissioning process should be conducted by a group of highly qualified personnel and experienced professionals [27-30].

In this activity also, we must have a general description that portrays the system as a whole or subsystems in need of commissioning, including the basis for the functions that is to be tested according to the marked-up P&ID [31, 32]. The next crucial element is the list of equipment to acquire for a temporary period of time or to be purchased permanently. Before even stepping to the site, proper purchasing or rentals of equipment must be listed out based on the contract requirements by the manager [33-35]. These equipment includes lubricants, tools, transportation requirements for personnel, computers, printers, and software for commissioning offices, consumables, spare parts, temporary pumps, hoses, plastic tubing and fittings, storage container for equipment that has been temporary removed from the plant and many more according to the type of plant that is to be commissioned.

The health, environment and safety aspect must also be considered during the commissioning process, where safety acts as one of the most crucial element in any type of power plant especially in a nuclear reactor. Activities that involve the operation of installing a nuclear-based applications may lead into many risks that involves safety. This is due to the possibility of hazardous radiation effecting the surrounding people and also the environment during normal or critical (accidents) conditions[36]. Then there is the preservation of the system where it is required to remove any existing preservatives within the system. In this procedure, the old preservatives are subsequently replaced with new ones considering the system will be out of service and unable to continue

operation for a period of time[37, 38]. The step by step detailed working that was prepared during pre-commissioning must be executed that includes the commissioning preparation, and the checklist. All the irregularities or faults shall be logged and recorded. Other than that is the incorporation of all the supplier's equipment for the start-up procedures. Before the proceeding of the handover of the plant to the asset holder, all the final planning of the commissioning execution phase is conducted, where the man-hours for the personnel per discipline is also taken into account [39]. The moment at which a capital project is completed is not the moment when the life of the facility commences. It is important to keep in mind, because the manner by which the design information is completely transformed and transferred for the operational phase can have a profound effect on the facility's long term success and profitability. This is what you call the hand-over phase [40].

The last main activity for a commissioning of a power plant is the documentation and the handover to the operating body. This process has its personal procedure because as stated earlier the handover process is quite tedious because all the information about the plant is needed to be transferred to the asset holder before operation can commence. It follows a formal procedure by least that this procedure consist of the commissioning of P&ID that portrays the completed system, the certificate that involves the acceptance of completion (signed by both parties), authority certificate, and operational procedures and handbooks. This review paper studies the comparison of the commissioning of a nuclear reactor power plant to any conventional power plants that is available around the world today [41].

2. Nuclear Power Plant Commissioning

The commissioning is an essential to the following secure operation of the Nuclear Power Plant (NPP). So, it should be planned early in the design and acquisition process and executed carefully according to acceptance criteria and test methods. The commissioning results should meet design requirements. The preliminary characteristics of systems and equipment should be define the source provided is values for normal operational tests. Nuclear power plant systems, structures and components are verified to comply with the design, put into the operation mode and tested which all these activities covered in the commissioning.

2.1 Commissioning Programme

The entire activities to be executed on systems, structures and components to fabricate their functioning according to the layout requirements are cover inside the commissioning programme. The conditions of NPP are considered in safety analysis report which the plant constantly in cozy area and the sufficient edges between the design purpose and safety demands and the real overall execution of the plant. The tests performed on the site might be different from off the site tests. The on the site test should recollect to the fullest viable of the off the site tests. The applications to structures, systems and components that mounted and integrated with their physical and practical interfaces in the NPP should go through justification adequately when test. Since NPP involving chemical materials, the commissioning programme includes the attention of chemical preconditioning and passivation of the plant precedent to active commissioning. In order to reduce the radiation dose to personnel in subsequent operations, the conditioning of the plant will diminish the subsequent corrosion fabrication, activated products and contaminated materials [42].

In commissioning programme, despite the safety is the most important thing need to be priorities, the responsibility allocation for safety at different milestone also should be adequately provision. The transport of nuclear fuel onto the site and secure nuclear fuel storage consisting access

control to buildings and the operation and monitoring of applicable systems. The loading of first fuel and first insertion of moderator and/or reflector, thereby linking duties for safety with responsibilities for operation of the plant.

The tests are carried out in a logical series to be progressive in order the plant is uncovered to less oppressive situations before leading to greater inconvenient conditions. Commissioning tiers are from non-nuclear testing tiers to nuclear testing tiers, and also from single components and system to comprehensive testing stages for homogeneous systems for the plant at the end. Operations personnel, maintenance personnel and support personnel are ensure participating in commissioning activities are further trained and qualified. In order to proceed in the process of commissioning, it is require the regulatory body's authorization milestone which identification of milestone is included in commissioning programme.

2.1.1 Commissioning organization

The operating organization (licensee) of the NPP is assigned as the chief responsibility for safety. Before starting of commissioning, the management system is established earlier. This system involving all items, services and process concerning to commissioning safety. Apart of that, management system as the components in establishment of policies and enabling the achievement of the objective in efficient and effective manner. All the activities regarding operation at once and not directly is included on this responsibility which incorporates the authority on supervised of all related organizations along with designers, providers, manufactures and constructors, employers and contractors along with the obligation for operation of NPP.

2.1.2 Feasibility study

A feasibility study is an analytical tool used during an enterprise development method to reveal how a business would function beneath a set of assumptions. Era used such equipment and manufacturing procedure, financing encompass the capital need, volume and value of products, and advertising and marketing regarding the costs and opposition are the factors that protected within the assumptions. Key portions and facts about the project are foregather into one comprehensive evaluation in the undertaking development process. The main motive of this feasibility study is to regulate whether the business opportunity is possible, practical and achievable[43].

2.1.3 Nuclear power plant siting

Site selection of new NPPs, related to the investigation of a massive place to pick desired sites, and accompanied by way of distinct evaluation of the favoured site. After the site has been investigated and analysed, siting standards are used to evaluate unique site related problems, activities, phenomena, hazards and different concerns. The local analysis is carried out to discover capacity sites using well established regional criteria. Local standards are typically related to national domestic policy, country wide financial policy, national and global environmental protection or other related rules of the State. Technical constraints and the availability of resources along with infrastructural constraints and availability of water on a local foundation are also vital concerns for regional analysis. There are two essential considerations in evaluate a potential site for a NPP which are site characteristics that have possibility effect on the safety of the plant or the transfer of radioactive material and also the potential consequences of the plant on the surrounding area, population and environment [44, 45].

2.2 Commissioning Execution

The power plant need to be abundantly complete to illustrate that it could be operated in all modes because it has been designed to be operated which fulfill the center of commissioning programme, testing. If the plant meet the situations which include the plant determined to be safe without been analysed or it is miles fall out of the range of assumptions made in protection evaluation document and they could damage the plant or threaten its safety, then the tests should not be achieved and the running modes or plant configurations status quo ought to not be implemented. Before the initiation of each test, a risk assessment should be done and any required precautions need to be taken in according with its findings. Identification and executions of structures, system and components should be done. An appropriate and vast tests of the safety capabilities for the NPP also need to be execute.

2.2.1 Safety, health and environment

The intention of protective human lifestyles, health and environment have in common in safety and security measures. Safety and security measures must be designed and applied in an integrated way in order that security measures do no longer compromise security. International Atomic Energy Agency (IAEA) is an international centre for cooperation in nuclear field that works with its Member States and various partners to stimulate the safe, secure and non-violent use of nuclear technologies global establish the fundamental of safety concepts, requirements and measures to manipulate the exposure of radiation and radioactive material release to surrounding. The establishment of safety fundamental are to ensure the protection of people and environment from ionizing radiation that harmful effects and to prevent the probability of events consisting loss of control over nuclear reactor core, nuclear chain reaction, radioactive and radiation sources, and to reduce the outcome of such events to occur.

2.2.2 Commissioning planning

The duration of state being inactive and the construction of other equipment might adjust the test outcomes of equipment that had been commissioned during the construction of NPP. The standby components that regularly not operated should consider in the planning of commissioning tests. The procedures and specific programme should be written in assisting of the commissioning programme. The principles, objectives and nature of the tests should be describe in the procedures and these programme. They should encompass the standards for judging the validity of the effects and the recognition standards. These approaches for systems crucial to safety ought to include assessment that overall performance tiers and running parameters were validated for all operational states (normal operation, predicted operational occurrences) and for coincidence situations to the volume viable, without threaten protection either without delay or not directly [46].

2.2.3 Environmental issues

In the first phase of a nuclear power programme, the environmental issues is consider to an informed decision for a nuclear programme. Reviewing the suitability of the existing framework and organizational shape chargeable for environmental protection and with a plan on determination of scarcity. Besides, initial siting survey, which encompass the initial environmental statistics series and

analysis. The second phase embody essential preparatory work for the deployment of nuclear power. Ideally, the implementation of the motion plan on legal, regulatory and organizational enhancements for environmental safety. Next, allocation of duties and establish decision making and licensing processes and environmental impact assessment (EIA) system finishing touch, with improvement of the three reviews which is preliminary environmental statistics analysis, the environmental scoping report (ESR) and the EIA report, comprise the EIA results to prepare the bid invitation specification or contract. The third phase satisfy the specification and concludes with the NPP prepared for operation. All the obtain licenses and permits for environmental necessity are needed during this phase. The development and implementation of environmental monitoring are also in this phase. Figure 1 shows the environmental issues according to the phase.

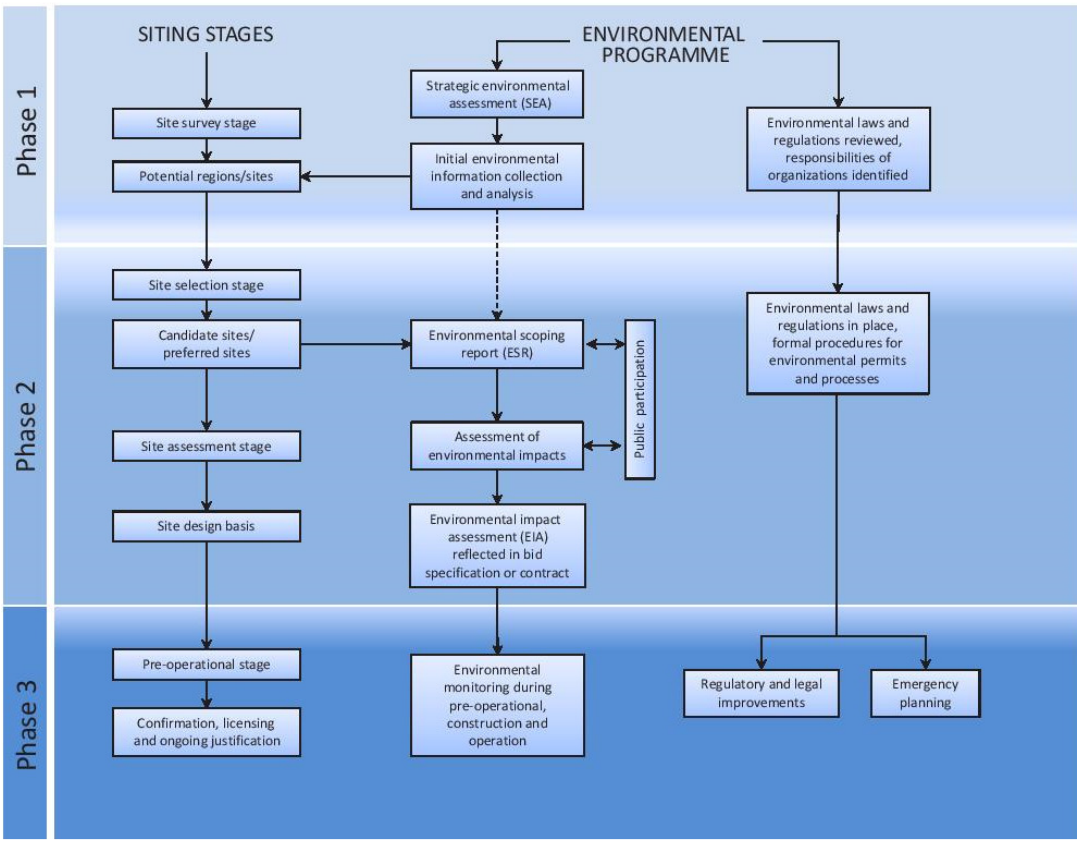


Fig. 1. Phase approached to environmental issues in nuclear programme

2.3 Documentation and Operation Hand Over

The commissioning documentation is essential for the succeeding thoroughly operation of the plant. The structure, content material, quantity and control of commissioning files are being distinct inside the control system of the operating organization. The arrangements of documentation are provide the progression of commissioning activities to ease the execution stages. Besides, the documentation as the evidence of design requirements had been fulfil or appropriate modification made are recorded. Information of the document supply warranty to the operating consortium that commissioning is proceeding effectively and as the records that to be had been kept for the lifetime of the plant [47].

The foremost cooperation from the commissioning association compose the Tier-I documents, illustration, and references in keeping the regulatory safety guides, safety evaluation review and probability encounter. Well before the field commissioning activities begin, the individual commissioning groups compose Tier-II documents for their framework and make certain such documents are made accessible to all different commissioning groups. A standard list of such file is provided in Table-1.

Table 1
Documentation Prepared During Commissioning

Documentation prepared by the top level team in the commissioning organization	**Typical numbers**	
Station Norms	22	
Regulatory submission for various stages of commissioning	7	**Tier-I documents**
Master commissioning network	1	
Documentation Prepared by commissioning groups		**Tier-II documents**
Commissioning Procedures (Vetting done by NPCIL Designer)	369	
Equipment level maintenance procedures	337	Documents required for Commissioning
Commissioning reports (Concurrence by NPCIL Designer and review by Regulatory Body)	369	
Operational flow sheets	195	
Operating manuals	175	
Operating procedure checklists	300	Documents required for Plant operation
Surveillance test procedures	120	
Emergency operating procedures (in collaboration with NPCIL Designer and safety analysis group)	62	
Training manuals	41	Documents required for O&M Training
SAT based checklist for station licensing programme	-	

Documents are composed and issued for the handover of plant structures to confirm officially that the system of the plant had been installed and examined as required underneath the commissioning programme and the system is functioning according to the layout requirement and allocation. The handover authorization are increase by means of the handover recognition package. The transfer of documentation is a purpose of the handover process. Documentation been conveyed in system packages and enable the plant personnel make a whole overview for each packages. These transfers are relying at the obligations allocated for the testing after fuel loading, at initial criticality, at low power and at increasing power level. The documentation on commissioning are blanketed the assisting records supplied in the configuration of guidelines or methods which are needed to help the activities inside commissioning procedure. Specimen of such files are records associated with the fuel assembly points and other nuclear materials, approaches for radiation protection and safety, and associated statistics. Any relevant reference additionally blanketed within the documentation.

3. Standard Commisioning Procedure and Operation

Commissioning can be described as the process in which the facility, plant or equipment is certified in congruent to the design purposes, particularization and industrial tests. A typical commissioning process can be classified into commissioning preparation, execution & documentation and last but not least is the handover to operation. These processes are the proof record that the machinery, appliances or system have been installed or modified are capable to perform in compliance to the specified requirements. Furthermore, commissioning is critical to ensure that the equipment or system is safely brought into service before handing the plant to the asset owner[48, 49].

Figure 2 shows the typical commissioning and start-up process flow of a power plant. Commissioning involves all activities from mechanical completion down to the certification of guarantees exhibited in the contract between the owner and the EPC (engineering procurement and construction) contractor. Once the certification is done, the project reference documents from the tests will be assemble. The documents involved are the installation, operation, and maintenance manuals such as the design drawings, factory test report, vendor drawing, project one-line diagram and purchase order. Next, the test data sheets will be reviewed to ensure that it is done correctly and completely. Lastly, the test data records will be collected to be transfer to the maintenance and operations personnel.

3.1 Commissioning Preparation

The commissioning preparation that is also known as the define phase, consisted of the development of commissioning organization that will conducted the feasibility studies that include the development of framework breakdown, packages definition, schedule, and authorizing budget plan and commissioning check record.

3.1.1 Development of organization

First and foremost, the development of commissioning and start-up (CSU) organization is the main priority. Prior an industrial power plant to be permitted before being constructed, an engineering study is required to be done. This study must prove the feasibility of the plant via determining the electric and thermal loads and cost approximation. Hence, this feasibility studies will be conducted by the organization that was develop beforehand. CSU organization must consist of engineering staff of adequate size and experience to make the preliminary studies, evaluation of bids and awards contract, and supervise the construction to ensure that it will be done of the time and budget that is allocated. The CSU team is responsible to provide consultation and expert to the project team leader all through the project framing and concept selection[50].

However, the detailed design is usually performed by a separate engineering company that specializes in respective aspects. Figure 4 illustrated the example of organization that can be established for the commissioning process. The amount of skills and roles needed and obligation of each personnel will differ dependent on the project phase.

Nonetheless, the basic responsibilities for each personnel are selecting the facility concept, development of implementation approach, interpretation of work extension, bidding and selection of contract, preparation of commissioning phase activities, implementation of phase and oversee the start-up, commencement of ramp and operation to ensure the reliability and performance of plant satisfied the operation acceptance[51].

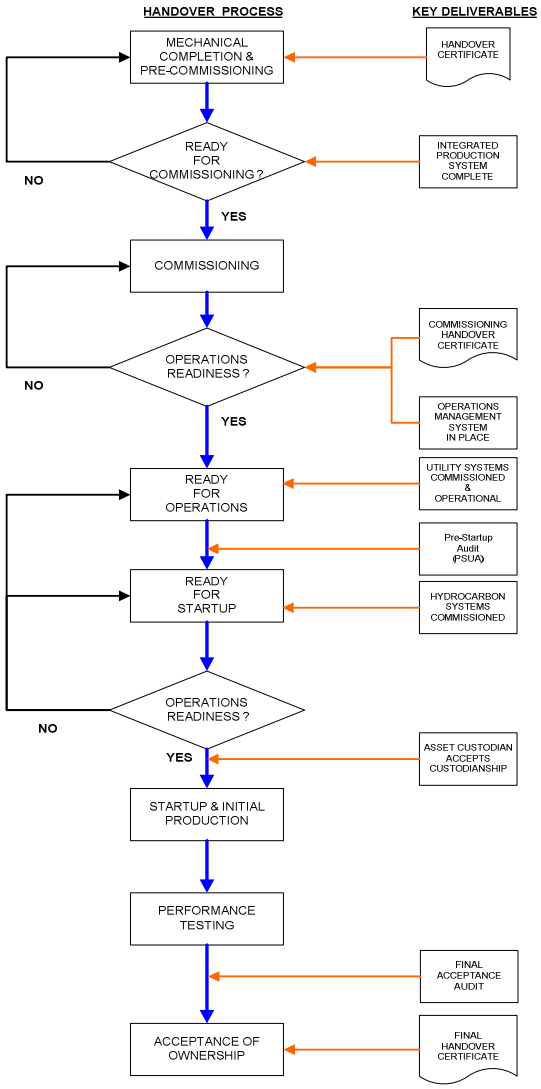


Fig. 1. Typical Commissioning and Startup Process Flow

3.1.2 Feasibility studies

Feasibility study is crucial in obtaining capital funds. This study is critical as they consider the total investment and evaluate the operation, maintenance, depreciation, insurance, interest and taxes. Moreover, this study must be written in such a way that it can be understood by those with finance or law background rather than engineering as this study primary emphasis is on the economics aspects. This economic analysis required documentation of historical steam and power requirement. Apart from that, another essential aspect of feasibility studies is the charting of the anticipated load for assorted condition such as daily load curve on different climate (winter, summer) and days (weekend, weekday, holidays). Furthermore, special consideration must be given any unexpected operating condition and the time of peak loads.

3.1.3 Site selection (siting)

Factor such as accessibility and availability of essential energy such as coal and water must be considered when settling on the area of power station. Siting additionally should be chosen in view of the capacity at that the station can be further developed into a national transmission network. In addition, site selection need to guarantee that the effects of the power station and its related framework on environment and the local neighborhood so that they will only have a insignificant and non-definitely impact. Apart from that, siting also must consider the power capacity of the power plant, duration of construction, gaseous and particulate emissions, capital & operating costs and the availability of employment or manpower. Basically the main priority of developing a power plant is the accessibility and availability of fuel source and water. Once the potential locales have been distinguished, they will be narrow down further by applying more detailed criteria.

3.2 Commissioning Execution

On the other hand, the commissioning execution can be described as the phases where the CSU execution team is mobilize in accordance with the mobilization plant and strategy. This process compromise of mechanical completion and execution of the pre-commissioning and commissioning. In general, this phase consisted of the following activities such as a list of possible risk that concerns the health, environment and safety must be made. The most critical process during the commissioning execution is the detail planning of the commissioning that will ensure the commissioning to be done within the time and budget that is allocated. In addition to that, construction phase that is awarding of contract (list of the consumables, temporary equipment tools and supplier assistance), site establishment and construction are the process in commissioning execution. The style of contracting and execution strategies are different from one project to another. They depend upon the market place and local requirements.

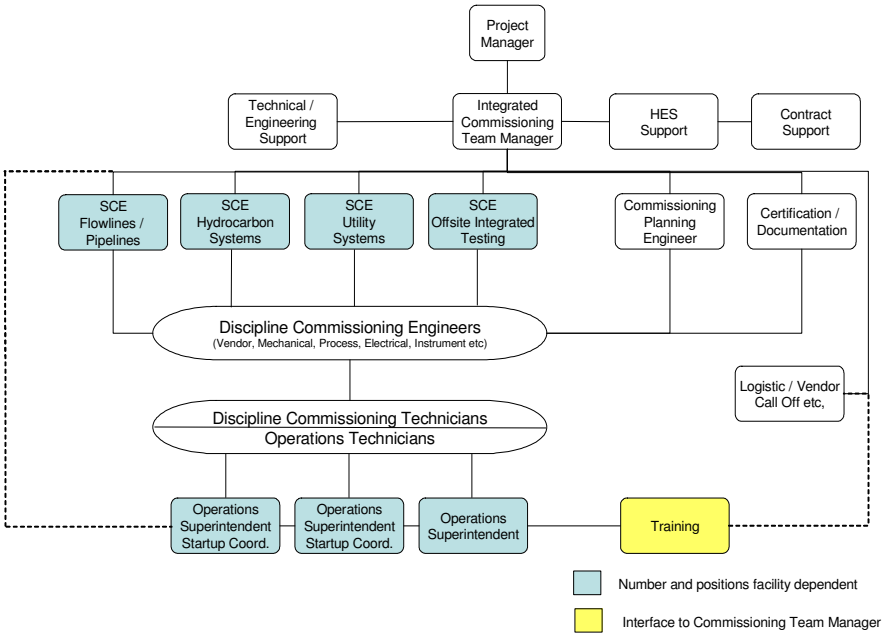


Fig. 3. Project and/or Contractor Commissioning Team's Organization Chart

3.2.1 Health, safety, environment and security (HSES)

All through the construction period of any task the site & labour security and HSE prerequisites are administered by the Projects HSE Manuals & Policies and HSE Plan. During the midst of progress among the asset operation and project development, commonly the HSE area for commissioning aspect can become a hazy region. It is, along these lines, particularly vital that the security prerequisites and standards for Commissioning activities are drafted, concurred and solidly set up a long time before these Commissioning activities begin. They must be developed prior the Project and Operational HSE Plans are concluded. Every project may vary regarding plant/hardware category, site, scope and labour, thus, the HSE standard and prerequisites will varied from one project to another. Hence it is fundamental that all aspects are reviewed and the possible risks occurrences are documented. This procedure must be prioritise to assure that sufficient time can be allocated for the accurate mitigation measure to be implemented in reducing the risk of ALARP.

The HSES assessments are also known as the Technical Area Overview assessment is conducted to ensure that the plant construction does not affect the health, environment and safety of the public. The critical activities that are conducted in this assessment are the identification of major construction and commissioning hazards, development of HSE plan framework, evaluate contractor HSE Plan and award contract and execute construction and commissioning accordingly to the HSE Plan. Apart from that, this assessment describe and include about how the existing environment will respond towards the proposed project and whether the facilities can be developed and operated securely and dependently align with relevant laws, mandates, directions and principles (LORS). Table 2 discussed the main HSE risk during Commissioning and Start Up their Close-out Response.

Apart from that this assessment, also state the ecological consequences of the project including potential general wellbeing and security impacts, mitigation procedure and potential organizations and interveners which may reduce or take out potential. Furthermore, this assessment also states the proposed conditions under which the project ought to be built and operated if it is approved and other project alternatives. In detail this assessment also record the air quality, public health, transmission line and security, dangerous materials, waste administration, land utilization, traffic and transportation, 'clamor, visual, socioeconomics, biological and cultural assets', soil and agrarian assets,, water resources, geological resources, paleontology resources, facility configuration, generating efficiency and transmission framework engineering.

3.2.2 Commissioning planning and scheduling

An effective and a thoroughly well done planning and scheduling have a significant effect on the consequent project cost. Although it is speeding up the duration of projects are compelling, in any case it is more crucial commit adequate time and assets to get the outline and execution components to ensure that they are correctly done.The project execution procedure should characterize and scope the primary project stages and the sequence of priority of the should be determined. Figure 5 & 6 illustrates the commissioning procedure process and building blocks diagrams that demonstrates the connections of the important stages in an offshore project and start-up logic. The main objective of planning is to characterize the methodology, principle and documentation used in the preparation & execution of the mechanical accomplishment, pre-commissioning and commissioning activities [52].

Planning stage is compromise of the milestone setting, commissioning budget and the methodology to implement the commissioning and completions activities. In setting the milestones, the milestones are development in accordance of the project phases. The milestones are pivotal as

they give focus & structure to the framework and as verification means that the plant are ready to be commissioned. On the other hand the commissioning budget compromise the project CSU team costs, project and in addition the contractual worker's protuberance or potentially refundable amounts for the preparation and execution of work. Meanwhile, the commissioning schedule is essential in to ensure that the plant can be completed within the time and budget allocated. The schedule that is managed must be practical and cost effective.

Table 2
Main HSE risk during Commissioning and Start Up their Close-out Response

No	HSE Risk	Close-Out Response
1	Non-Hydrocarbon or Hydrocarbon systems leaks.	Utilization of Flange Management program in place and emergency response training particularly for leaks.
2	Introduction of pressurised nitrogen for testing.	Give training to all staff about nitrogen and make sure the procedures for pressurized plant are oblige. Ensure all vent ways and lines are indicated.
3	Shortcutting of procedures (e.g. safeguarding) or human errors due to stress (or alarm overkill).	Set up procedures with assistance from start-up administrators who have experience. Provide training to all staff about start-up plan.
4	Non-adherence to commissioning procedures or start-up plans.	Create start-up plan with help of experienced start-up personnel. Give training to all staff about start-up plan and process and apply consequence management (Lifesaving rules).
5	Inadequate identification of energized equipment.	Follow tagging/lock procedure. Give clear ID of live hardware and lines.
6	No clear demarcation between construction and live areas of plant.	Barricade the live region and plant with striped plastic tape, hang relevant warning signs and control access.
7	Use of sub-standard temporary equipment (e.g. hoses, heaters, burners).	Ensure that all temporary appliances and hardware liable to engineering discipline review to affirm technical integrity and that CSU personnel are trained to used them.
8	Use of hazardous chemicals.	Utilize MSDS and HEMP to recognize vital controls.
9	Drainage system becomes live (hydrocarbon contamination).	Observe drainage specification. Clearly identify live systems.
10	Inadequate or incorrect identification of system boundaries and isolation points.	Framework limits reviewed by senior commissioning engineers. All framework limits drawings and isolation points are marked up and frozen
11	High-temperature lines, un-insulated flanges, etc.	Utilize cages or guards to cover the high-temperature flanges/valves/lines. Barricade the region.
12	Commissioning personnel and resources not familiar with equipment.	Allocate sufficient time to hire personnel and determine the correct competency levels for all commissioning staff.
13	Overfilling of flare KO system during commissioning.	Train operators. Use correct commissioning procedure.
14	No clear or unclear line responsibility during start-up.	Concurred obligation matrix and strict communication protocol developed and put in place pre-Start-up.
15	Lack of understanding of CSU hazards/awareness of the frequently changing site conditions	Give training to all staff. Utilize HSE meetings, bulletin boards and Tool box talks to update affected workforce of changing site conditions.

Figure 7 demonstrates the guide and succession in activities to build up an appropriate and coordinated CSU schedule. In order to develop a fully integrated CSU Schedule, right off the bat, the systemization should be actualized ahead of schedule in the project where the terms, characterization of project phases, and milestones are unmistakably define and concurred as a part of Project Handover process. The CSU schedules are compromise of resources, work scope, logical

relationships, contractual milestones and interfaces with the outside world. The CSU schedules represent the timeline of the CSU information and phase the from the activity lists. Once the approximation durations of the activities have been overlays and the commencing dates for commissioning per framework are included, a Gantt chart such as Figure 3.2.2.4 can be produced.

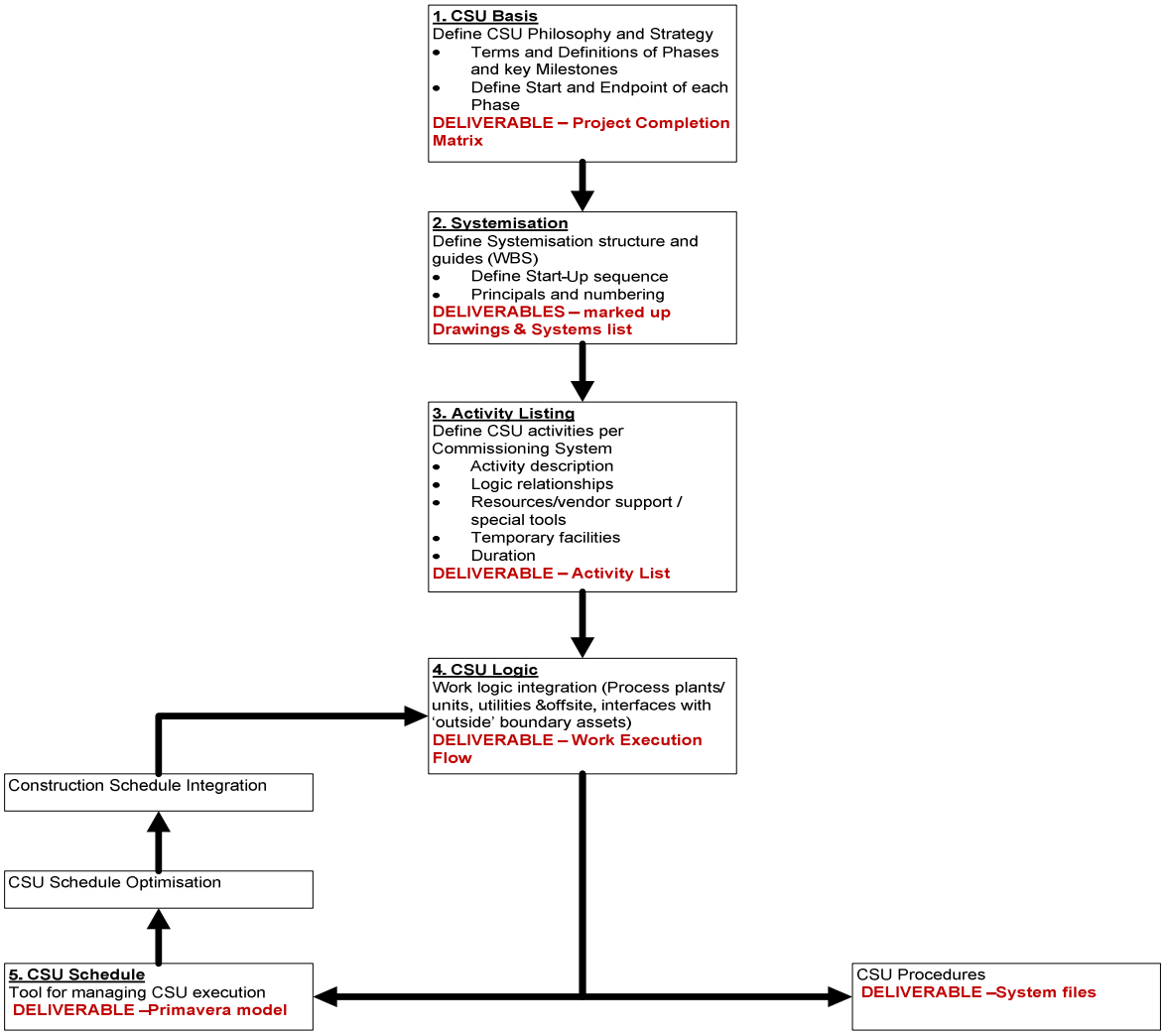


Fig. 4. Integrated CSU Schedule Roadmap

3.2.3 Construction phase

Construction stage can be characterized into awarding of contract, site establishment and construction. The following period of site establishment is the phase comprise of the framework arrangement needed for the principle contractual workers to commence their work. During this phase, the water flow & sewerage and electrical services will be constructed. Apart from that, the land also will be leveled and the roads and offices will be develop and establish. In addition, the landscape also will fenced, security control and emergency treatment offices also will be set up[53], [54].

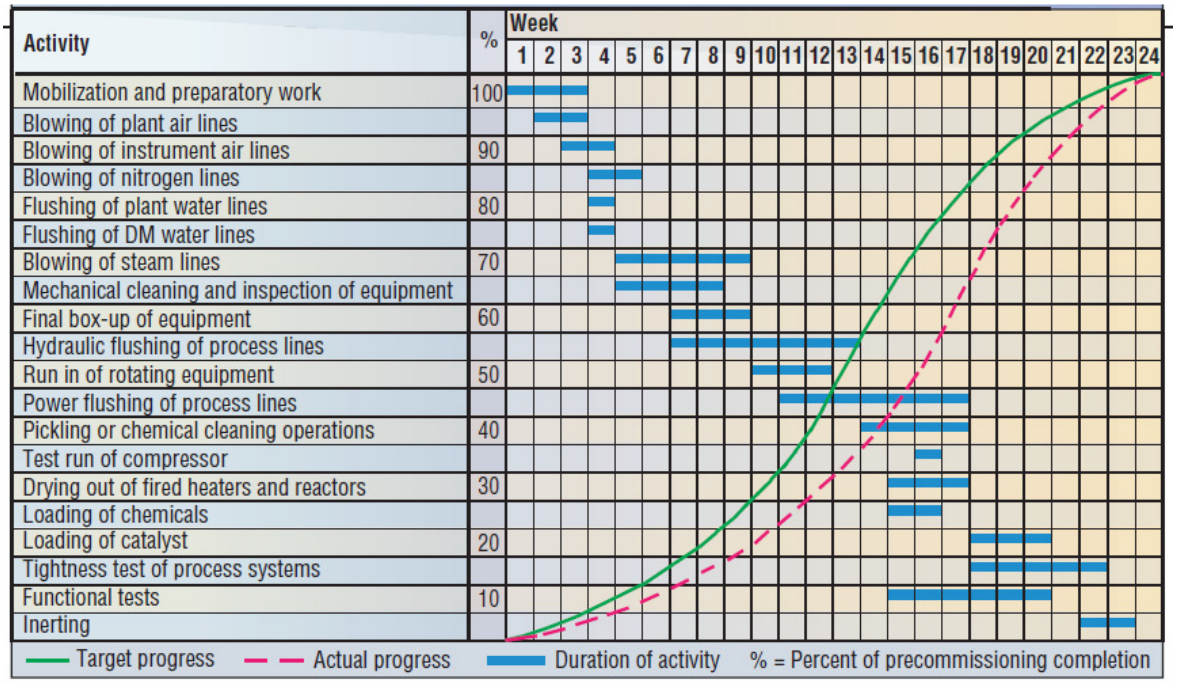


Fig. 5. Pre-commissioning Gantt Chart

Figure 9 illustrates the commissioning and startup delivery whilst Figure 10 shows the project completion flowchart of the construction through commissioning into operation.In creating an integrated Mechanical Completion, the CSU plan need to align with the construction plans. The construction begins with the excavation and setting out of foundations. Trenches and pipe work must be placed and done before construction of the turbine hall started given that the power station utilizes a wet-cooling system. Although numerous sites are under construction simultaneously, mostly the constructions will be focusing on the groundwork of the boiler regions, cooling towers, turbine section and stacks area[55]. Generally, duration of siting, construction until commissioning of the boiler and turbine, consume relatively about four to five years. The duration however varies from one project to another and depends on the complexity of the plant.

3.2.5 Commissioning (Plant Start-Up)

After the construction stage is completed, the plant will proceed with acceptance inspection and testing right before the plant can commissioned. They are performed to achieve the mechanical completion and are conducted on a single discipline basis. These activities do not require the systems or equipment to be power up. However, they may need the bench calibration of instruments, electrical continuity & insulation tests, valve's integrity test and hydro testing of pipes. Once the testing and inspection is done, they commissioning will begins with the auxiliary plant systems in order to give logistical support for turbine and boiler operation[55], [56]. Apart from the auxiliary system, the coal supply and ash handling systems, water treatment, transmission network and the electrical supplies will also be commissioned before the boiler and turbine. Furthermore, fundamental appliances and machinery such as engines, lights, pumps and control circuits are among the primary system that will be commissioned. The commissioning of boiler and turbine originally comprise of the cleaning of all steam, auxiliary and water pipework. Once the commissioning is done

and the system is fully proven to acquire the steady-state operations, it will be handover to the future asset owner's organization.

3.3 Commissioning Documentation and Handover to The Operation

Last but not least, the final step in commissioning is the documentation and handover to the operation. Table 3 illustrates the handover steps. Prior to the plant handover to the proprietor, the contractor is requisite to handover various areas of the plant to the owner accordingly to the order of completion. The audit is done by the owner's personnel and they will be thoroughly checking each unit with respect to the P&IDs and piping, instrumentation, electrical, & structural requirements before taking over. Once the audit is done, the owner will produce a list of defected system or equipment that his team identified during the audit. Upon the list, the contractor will rectify the fault and lastly the owner executes a final inspection. The audit is regard as completed once owner is pleased and convinced. Every handover and acknowledgment should be upheld with the relevant documentation as demanded by the CCMS and concurred by both parties. Apart from that, feasible operation in a steady-state condition is evidence that is required[57], [58].

This assessments show that the power plant has achieved the required reliability and efficiency with regard to the asset and design integrity. This process must be completed before the plant handover. In addition, by conducting this assessment it infers to the understanding to transfer the asset from the project delivery team to the operations group. Once the formal handover of plant is completed, the Asset Holder becomes the true owner and responsible for operating and maintaining all areas of the plant and the Project Director/Manager will be automatically released from all obligations towards the asset. The subsequent pre-conditions appeal related to the Acceptance and Handover of Ownership where the amenities, appliances, and machinery are demonstrably secure, proficient yet continuous. Nevertheless, it still met the overall performance admission acceptance standard, which include availability. In addition, the Asset Holder also wll receive the facility in accordance where all contracts closed or transferred and all related data and documentations are handed over and in a pre-agreed format.

4. Discussion

In commissioning, there are various parts of subtopics that need be covered. Therefore in this section, graphical displays such as table are done as the simplified form. Table 1 shows the requirement for organizing the commissioning[59].

Table 1
General requirement for organizing the commissioning

Nuclear Power Plant	Conventional Power Plant
Licence-holder must be obliged for nuclear and radiation safety	The Contractor is liable for the commissioning process
Licence- holder shall plan and establish, a commissioning organization	The Contractor shall plan, execute, and document the commissioning work

Regarding the testing plan for the power plant, the table below show that for running a commissioning test on power plant need to have these criteria. It shows that for both nuclear and conventional has the criteria. Even though they have the same criteria, the method is different with the type of power plant[60]–[62].

Table 2
Testing plan for the power plant

Criteria	Nuclear	Conventional
Instructions and procedures are followed with the testing plans	√	√
Utilization of the gained experience with similar plants in planning the testing	√	√
Items identification of the plant that requiring special attention, and separate summaries of the tests to be carried out on these items	√	√
Preliminary estimation of the testing schedule	√	√
Testing roles for validating the plant operating instructions	√	√
An estimation of personnel required in the different organizations during testing	√	√

5. Conclusion

This paper reviews the comparison for the commissioning of nuclear power plant with others conventional power plant. First, is the explanation of the meaning of the term commissioning. Next this paper discusses the commissioning process of the nuclear power plant (NPP). Last but not least, general criteria of the commissioning for power plant are also explained.

Basically, commissioning process aimed to demonstrate that the constructed power plant has met the design and safety requirements as stated in the licence conditions and in the safety analysis report. However due to the radiation hazard from NPP, International Atomic Energy Agency (IAEA) has come out with specific objective guideline for the commissioning of NPP[63]. One of the guideline is to become adept in the operating, maintenance and technical staff of the nuclear power plant with the operation of the plant. This shows that main concern from the commissioning test is that they want the workers at NPP be aware of radiation.

Besides that, for other conventional power plant such as coal power plant which is the least costly and most accessible fuel has the same objective that is to validate whether the constructed power plant is according to the design criteria as proposed. Moreover most coal power plant prioritize the efficiency of the plant, whereas the overall efficiency is about 33% efficiency. In conclusion, this review paper is mainly the information that we have extracted from the paper from 1979 until 2017.

References

[1] IAEA, “Commissioning for nuclear power plants: safety guide,” IAEA Saf. Stand. Ser., no. NS-G-2.9, 2003.
[2] STUK/YVL A.5, “Construction and Commissioning of a Nuclear Facility,” no. 9, pp. 1–21, 2014.
[3] Integrated service solutions, “Commissioning,” 2016.
[4] C. Timothy, “Commissioning power,” Eng. Syst., vol. 16, no. 1, p. 100, 1999.
[5] STUK, “The Commissioning of a Nuclear Power Plant,” Nucl. Saf., no. 9, pp. 1–10, 2005.
[6] Shearman, R., S. M. Collins, G. Lorusso, M. Rudigier, S. M. Judge, S. J. Bell, Zs Podolyak, and P. H. Regan. "Commissioning of the UK NAtional Nuclear Array." *Radiation Physics and Chemistry* 140 (2017): 475-479.
[7] Wang, Zhiwei, Wugao Yu, and Shi Bo. "Startup, commissioning and operation of Fenyi 100MW CFB boiler." In *Proceedings of the 20th International Conference on Fluidized Bed Combustion*, pp. 137-142. Springer, Berlin, Heidelberg, 2009.
[8] IAEA, “Commissioning of Nuclear Power Plants: Training and Human Resource Considerations,” 2008.
[9] O. Notes, “Siting of Nuclear Power Plants,” no. March, 1997.
[10] IAEA, “Licensing Process for Nuclear Installations SSG-12,” 2010.
[11] Mukherjee, Siddhartha. "Preparations for initial startup of a process unit; here is what to do just after a new plant is built, to make sure it will have a smooth startup." *Chemical engineering* 112, no. 1 (2005): 36-43.

[12] A. Grieve, H. Ronteltap, and K. Wahaibi, "PR-1159 - Commissioning and Start-up."
[13] M. Killcross, Chemical and Process Plant Commissioning Handbook. 2012.
[14] Zerger, Benoît, and Marc Noël. "Nuclear power plant commissioning experience." *Progress in Nuclear Energy* 53, no. 6 (2011): 668-672.
[15] A. Alonso, Infrastructure and methodologies for the justifi cation of nuclear power programmes. 2012.
[16] I. Journal and S. I. No, "TECHNICAL AUDIT FOR PROFIT AND PERFECTION (A case study of Commissioning - Thermal Power Plant) Prof (Dr.) Shankar Bakhsh Srivastava 1," vol. 3, no. July, pp. 98–110, 2013.
[17] Moore, I. D., T. Eronen, D. Gorelov, J. Hakala, A. Jokinen, A. Kankainen, V. S. Kolhinen et al. "Towards commissioning the new IGISOL-4 facility." *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 317 (2013): 208-213.
[18] T. Group, B. P. Engineering, D. Engineering, O. Training, M. Completion, and P. Commissioning, "KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions Roles and Responsibilities of Plant Pre-Commissioning, Commissioning and Acceptance Test Run."
[19] KLM Technology Group, "Start-Up Sequence and General Commissioning Procedures (Project Standards and Specifications)," pp. 1–12, 2011.
[20] NRC, "Nuclear Power Plant Licensing Process," 2004.
[21] Michanek, Gabriel, and Patrik Söderholm. "Licensing of nuclear power plants: The case of Sweden in an international comparison." *Energy Policy* 37, no. 10 (2009): 4086-4097.
[22] Lawry, Kris, and Dirk John Pons. "Integrative approach to the plant commissioning process." *Journal of Industrial Engineering* 2013 (2013).
[23] Haire, T. P., and J. Shaw. "Nuclear power plant licensing procedures in the United Kingdom." *Progress in Nuclear Energy* 4, no. 2 (1979): 161-182.
[24] Black and Veatch, Power Plant Engineering, vol. 53, no. 9. 2013.
[25] Marscher, William, and Eric Olson. "Turbine problems threatened new plant commissioning: bearing problems were repaired without turbine disassembly." *Power Engineering* 113, no. 3 (2009): 66-68.
[26] Weltec Biopower GmbH, "Weltec biogas plant in Germany undergoes commissioning," Biomass Magazine, 2013.
[27] Bradt, M., E. Beckman, W. Dilling, B. Lanz, K. Louis, T. Nicolai, M. Starke, and C. Moeller. "Wind power plant testing and commissioning." In *Transmission and Distribution Conference and Exposition (T&D), 2012 IEEE PES*, pp. 1-7. IEEE, 2012.
[28] Huang, Bin, Shisen Xu, Shiwang Gao, Lianbo Liu, Jiye Tao, Hongwei Niu, Ming Cai, and Jian Cheng. "Industrial test and techno-economic analysis of CO2 capture in Huaneng Beijing coal-fired power station." *Applied Energy* 87, no. 11 (2010): 3347-3354.
[29] P. Kiameh, "COMMISSIONING AND START-UP ACTIVITIES OF COAL POWER PLANTS : Topics Covered Checks and Tests Commissioning Management System of Coal Power Plants Commissioning Procedures and Instructions for Boiler and Auxiliaries in Coal Power Plants Expert Course Facul," no. May, pp. 22–24, 2017.
[30] U Tveten, Ulf, Dag Thomassen, and Erik Kvaal. "Accident analyses performed for the norwegian commission on nuclear power." *Progress in Nuclear Energy* 4, no. 3 (1979): 215-254.
[31] E. Development and P. G. Committee, "IEEE Guide for the Commissioning of Electrical Systems in Hydroelectric Power Plants," 1998.
[32] G. Davis, "ENERGY COMMISSION ENERGY FACILITY Developers Guide of STAFF REPORT / DRAFT," no. November, 2000.
[33] Ando, Kenji, Eisuke Asada, Kenjiro Yamamoto, Toshihide Noguchi, and Yasuo Sumiyoshi. "Design, construction, and commissioning of the Nos. 1 and 2 units of the Ratchaburi Thermal Power Plant for the EGAT of Thailand as a full turn-key EPC contract." *Mitsubishi Heavy Industries Technical Review* 39, no. 3 (2002): 95-100.
[34] Cho, Baekhyun, Geunwon Choi, Yumi Uruno, Hyunseo Kim, Jaewon Chung, Hyojun Kim, and Kihyun Lee. "One-dimensional simulation for attemperator based on commissioning data of coal-fired steam power plant." *Applied Thermal Engineering* 113 (2017): 508-518.
[35] B Zerger, Benoît, and Marc Noël. "Nuclear power plant construction: What can be learned from past and on-going projects?." *Nuclear Engineering and Design* 241, no. 8 (2011): 2916-2926.
[36] International Atomic Energy Agency (IAEA), "Safety of Nuclear Power Plants : Commissioning and Operation," SSR-2/2, 2011.
[37] Grater, F., K. Ruhmann, T. Thaufelder, J. Trautmann, and I. S. C. C. Kuraymat. "Experiences and results during Commissioning and First Operation–Proc." In *Conf. SolarPACES2011-20-23 settembre*. 2011.
[38] Wirtz, P. "The erection and commissioning of the Mülheim-Kärlich nuclear power plant." *Nuclear Engineering and Design*100, no. 3 (1987): 297-306.
[39] Odakura, Mitsuru, Yutaka Kometani, Masahiro Koike, M. Tooma, and Y. Nagashima. "Advanced inspection technologies for nuclear power plants." *Hitachi Review* 58, no. 2 (2009): 82-87.

[40] Allevi, Claudio, and Guido Collodi. "The Sarlus IGCC project construction overview and commissioning experience." In *16th World Petroleum Congress*. World Petroleum Congress, 2000.
[41] Schumacher, Jürgen, Dirk Pietruschka, and Ursula Eicker. "Commissioning and operational control of photovoltaic power plants through online simulation." *Energy Procedia* 57 (2014): 152-160.
[42] IAEA, "Site Survey and Site Selection for Nuclear Installations," pp. 2, 20, 24, 2015.
[43] A. C. Fisheries, "Feasibility Study," Assessment, no. May, 2007.
[44] Martins, Vivian B., Tatiana S. da Cunha, Francisco Fernando Lamego S Filho, and Celso Marcelo F. Lapa. "Site selection process for new nuclear power plants-a method to support decision making and improving public participation." In *2011 International Nuclear Atlantic Conference–INAC 2011*. 2011.
[45] A. Energy, L. Board, J. Dengkil, and S. D. Ehsan, "Guideline for Site Selection for," 2011.
[46] Brinkmann, Gerd, and Michael Will. "Concept licensing procedure for an htr-module nuclear power plant." *Nuclear engineering and design* 121, no. 2 (1990): 293-298.
[47] Seitz, Hilary. "The power of documentation in the early childhood classroom." *YC Young Children* 63, no. 2 (2008): 88.
[48] T. D. Process, E. Affairs, and S. Selection, "Building a coal fired power station."
[49] E. I. A. Lester, "Project Close-Out and Handover," Proj. Manag. Plan. Control, pp. 405–407, 2014.
[50] Keatley, Patrick. "Cost modelling of coal power plant start-up in cyclical operation." In *Coal Power Plant Materials and Life Assessment*, pp. 358-388. 2014.
[51] Wieck-Hansen, Kate, Peter Overgaard, and Ole Hede Larsen. "Cofiring coal and straw in a 150 MWe power boiler experiences." *Biomass and bioenergy* 19, no. 6 (2000): 395-409.
[52] Sato, Susumu, Masahiko Matsuda, Takao Hashimoto, Yoshiyuki Wakabayashi, and Akira Hashimoto. "Design Features and Commissioning of the 700 MW Coal-Fired Boiler at the Tsuruga Thermal Power Station No. 2." *Fuel* 1, no. 1.51 (2001): 0-97.
[53] N. Standard, "Mechanical completion and commissioning," no. May, 1999.
[54] Tonti, A. "Residual life evaluation techniques, defect assessment procedures and monitoring in coal power plants." In *Coal power plant materials and life assessment*, pp. 199-228. 2014.
[55] T. Ü. V Rheinland, "Efficiency at the highest level . From the very beginning . We help you to save energy . Even in the planning phase ."
[56] I. Page, "Guideline for Testing and Commissioning of Small Hydro Power Plant for Feed-in-Tariff (FiT) Projects in Malaysia 2015," 2015.
[57] Rodríguez, Norberto Pérez, Erik Rosado Tamariz, and Rafael García Illescas. "Emissions and Noise Pollution Diagnosis of a Turbogas Power Plant During Commissioning Service." In *ASME Turbo Expo 2010: Power for Land, Sea, and Air*, pp. 1269-1276. American Society of Mechanical Engineers, 2010.
[58] Prieto, Cristina, Rafael Osuna, A. Inés Fernández, and Luisa F. Cabeza. "Thermal storage in a MW scale. Molten salt solar thermal pilot facility: Plant description and commissioning experiences." *Renewable Energy* 99 (2016): 852-866.
[59] Munuera, Antonio, JoséManuel Conde, and Julio Martinez. "Licensing requirements for initial commissioning programs in Spain: Application to different PWR designs." *Nuclear Engineering and Design* 127, no. 2 (1991): 207-213.
[60] N. Ng-t-, "IAEA Nuclear Energy Series Managing Environmental Impact Assessment for Construction and Operation in New Nuclear Power Programmes."
[61] Antaki, George, and Ramiz Gilada. *Nuclear Power Plant Safety and Mechanical Integrity: Design and Operability of Mechanical Systems, Equipment and Supporting Structures*. Butterworth-Heinemann, 2014.
[62] Norris, W. E., D. J. Naus, and H. L. Graves III. "Inspection of nuclear power plant containment structures." *Nuclear engineering and design* 192, no. 2-3 (1999): 303-329.
[63] Desai, N. B., Santanu Bandyopadhyay, J. K. Nayak, R. Banerjee, and S. B. Kedare. "Simulation of 1MWe solar thermal power plant." *Energy Procedia* 57 (2014): 507-516.

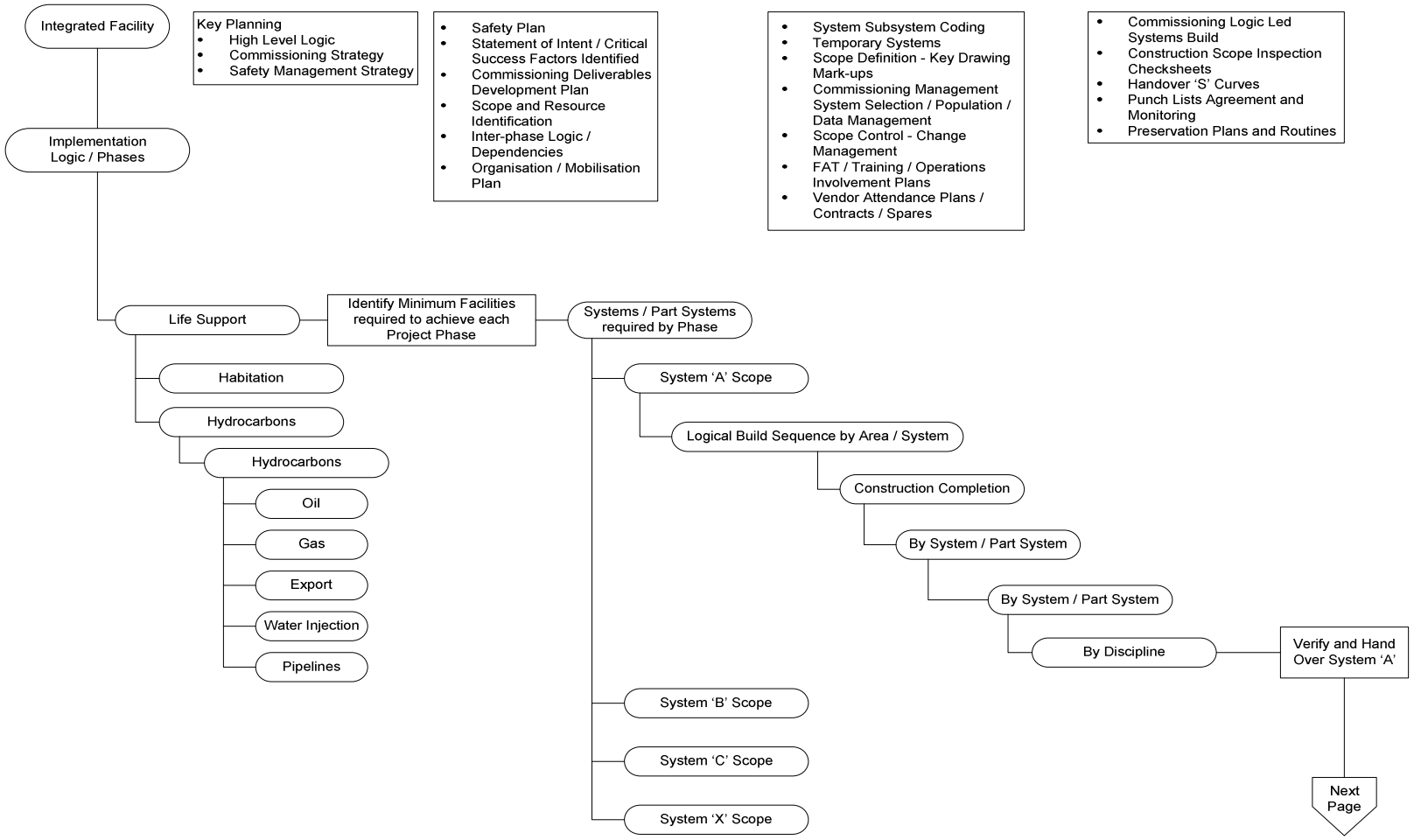


Fig. 5. Commissioning Planning Process and Building Blocks

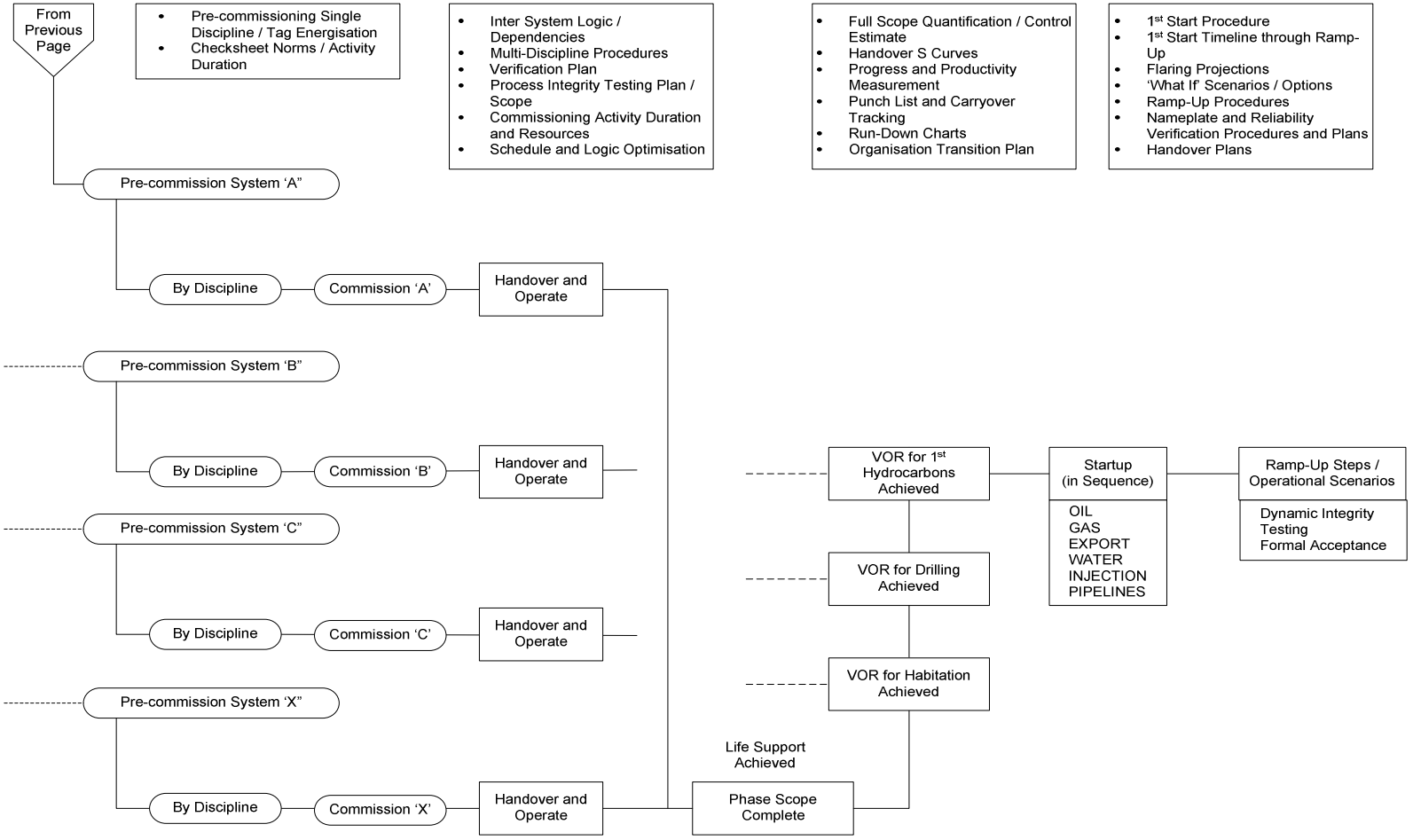


Fig. 6. Commissioning Planning Process and Building Blocks (Continued)

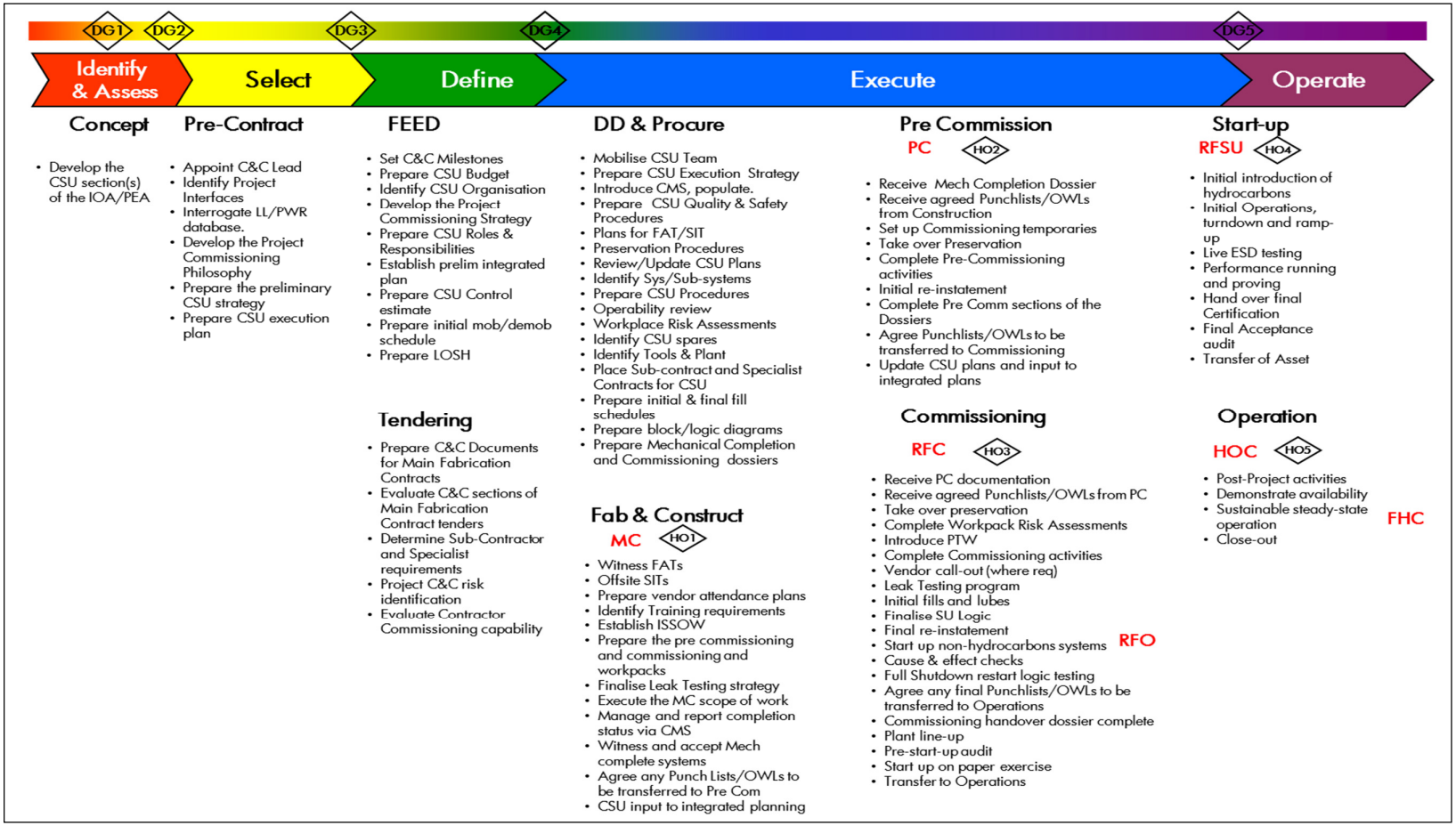


Fig. 9. Commissioning and Startup Delivery

Penerbit Akademia Baru

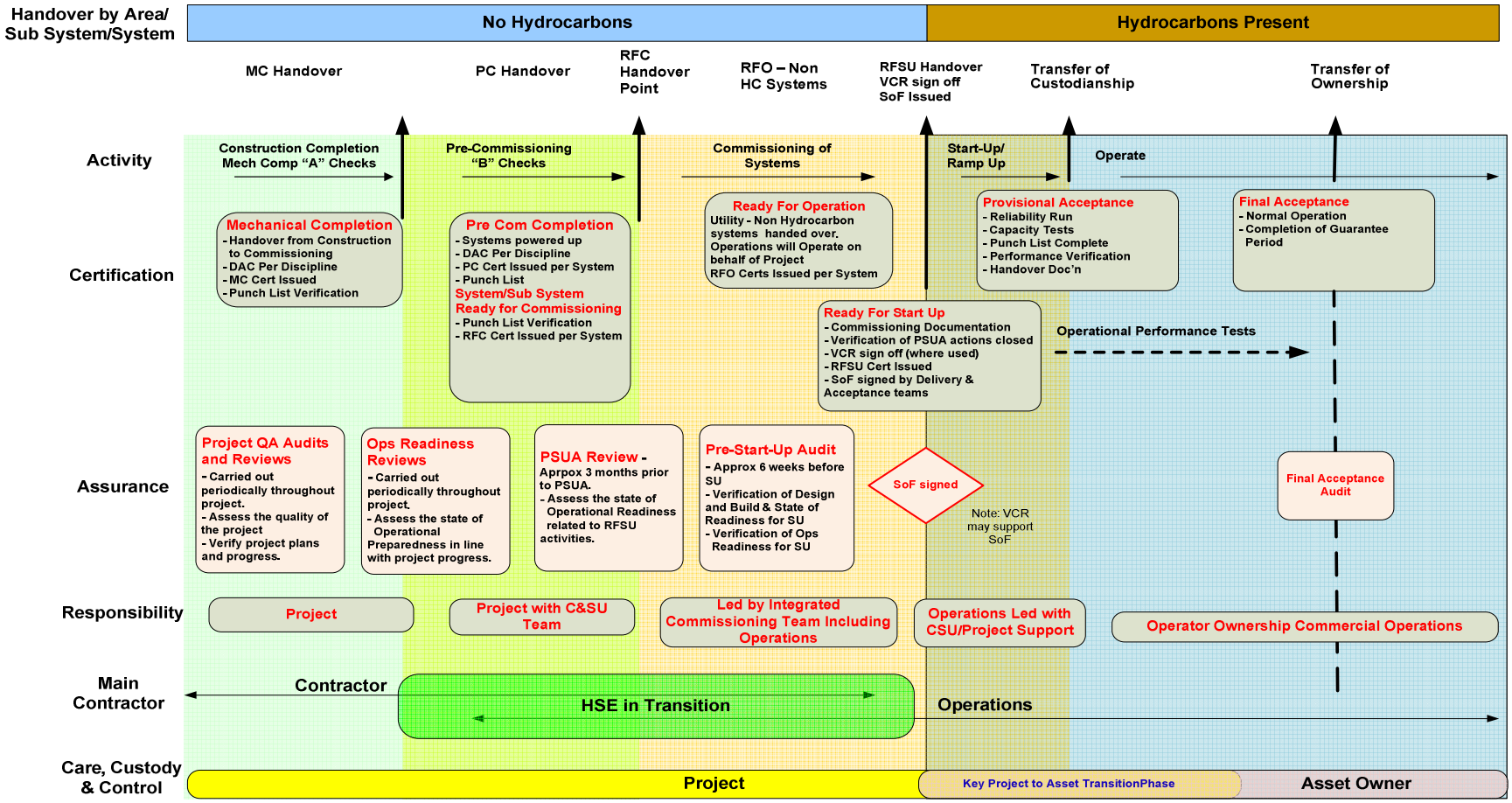


Fig. 10. Project Completion Flowchart of Construction through Commissioning into Operation

Table 3
Handover

Handover Point	Scope	Prerequisites	Documentation	From / Acceptance By
Mechanical Completion	By System / Subsystem (WBS)	Discipline Joint Punch Construction / Pre-Commissioning	Construction Handover Cert. As-Built's	Construction Responsible Person Pre-Commissioning Responsible Person
	By Discipline		System Acceptance Cert. / Verification of Completion Checksheets	
Pre-Commissioning Completion (RFC)	By System / Subsystem (WBS)	Discipline Punch Review	Discipline Checksheet Report System Checksheet Report	Pre-Commissioning Responsible Person Commissioning Responsible Person
	By Discipline			
Commissioning Complete (in support of milestone phase or RFSU)	By System / Subsystem or Milestone (WBS)	Commissioning / Operations Joint Punch List	Commissioning Dossier / System Handover Cert. / As-Builts / Verification of Completion Checklist Completed	Commissioning Responsible Person Operations Responsible Person
Ready for Startup (Interim for Operational Purposes)	By System / Subsystem or Milestone (WBS)	Area Handovers / Pre-Startup Audit / Punch List Review / Startup Procedures / Performance Test Procedures	Verification of Readiness for Startup Checklist	Commissioning Responsible Person Asset Operator
Handover of Custodianship	By Asset / Full Facility	Pre-Startup Audit carried out A Class Outstanding Punchlists cleared		Project to Asset Manager
Final Handover / Acceptance	Full Facility	Achieve Nameplate Performance / Commence Normal Operation / Guarantee Period Starts /	Final Acceptance Certificate / Performance Reliability and Capacity verification /	Project to Asset Manager