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Implementation study of an asset management system Within an Electricity Transmission Maintenance Unit at STEG

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Now, I have a new motto in my career: be innovative to add value

Thanks my God

Résumé

Destinée à œuvrer au niveau opérationnel, les bases de transport d'électricité ne peuvent pas rester isolées de leur environnement externe et interne.

En assurant leurs taches principales, la maintenance et la surveillance des actifs de transport, elles veuillent à la réalisation des objectifs de la STEG. Tenant compte des caractéristiques du domaine stratégique de transport d'électricité et du fait que la STEG est classifiée comme une entreprise d'infrastructure, le meilleur outil pour relier le stratégique à l'opérationnel et vis versa est l'instauration d'un système de gestion d'actif. La série ISO 5500x offre un cadre normalisé pour l'instauration de tel système au sein des bases de transport d'électricité.

Mots clés : STEG, Transport d'électricité, base de transport, Gestion d'actif, ISO5500X

Abstract

Designed to act at the operational level, the electricity transmission Maintenance unit could no more remain isolated from their external and internal environment. While ensuring their main tasks, maintenance and monitoring of transport assets, they shall achieve STEG's objectives. Taking into account characteristics of the electricity transmission business, and the fact that STEG is categorized as an infrastructure company. The best mean to link the strategic level to the operational one is the establishment of an asset management system. ISO 5500X series provide a standardized framework for the establishment of such a system within the electricity transmission maintenance units.

Key words: STEG; Electricity transmission, ETMU, Asset management, ISO5500X

ملخص

رغم أنّ صعيد عمل وحدات صيانة نقل الكهرباء يضل مركزا على الصعيد التنفيذي، فإنه لا يمكنها البقاء معزولة عن محيطها العام و الخاص .

فمن خلال قيامها بمهام مراقبة و صيانة معدّاتها، ترنو الوحدة إلى تحقيق الأهداف الإستراتجية للشركة (الستاغ)

أخذا في الاعتبار خصائص مجال نقل الكهرباء، وحقيقة أنّ الشركة تدير بنية تحتية واسعة. فإنّ أفضل وسيلة لربط المستوى الاستراتيجي بالعملي هو إنشاء نظام إدارة الأصول. حسب سلسلة المعايير 5500X توفر إطارا موحدا لإنشاء مثل هذا النظام داخل وحدات صيانة نقل الكهرباء.

كلمات مفاتيح: الستاغ ، نقل الكهرباء ، وحدات صيانة نقل الكهرباء ، إدارة الأصول ، 5500X

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Introduction

"A management system is the framework of processes and procedures used to ensure that an organization can fulfil all tasks required to achieve its objectives" Chris Anderson,[1]

This quotation summarizes the original idea behind this document.

In fact, STEG is the main actor in the Tunisian electricity market. As any company, it has strategic plan and objectives to achieve.

Obviously, there are a set of tasks that are necessary to fulfil the company's mission and to reach strategic objectives.

The main concern, which has always haunted me, is how through driving operational tasks and activities we could satisfy strategic aspirations.

Adapted to the study case, how an electricity transmission maintenance unit through its daily activities participates to STEG's strategy achievement.

The suggested solution is a management framework that fit to the transmission activity, addresses with the maintenance activities and allows the optimization of technical and financial performance of the ETMU. We propose the establishment of an asset management system.

[1] Anderson, Chris. How to Build Effective Management Systems, *Bizmanualz*, January 26th, 2005.

Chapter 1 :

Study’s context

1.1. STEG Presentation

1.1.1. STEG Mission

The main mission of the Tunisian company of electricity and gas is the electrification of the country, the development of the natural gas network and implantation of electric and gas infrastructures.

1.1.2. STEG Vision

STEG is engaged in a strategy of performance. It aims to provide a level of quality of services similar to the best Mediterranean companies of electricity and gas [STEG Official Site].

1.1.3. STEG Trades

The STEG is responsible of electricity and LPG[2] generation. It is also accountable of the transmission and the distribution of electricity and natural gas [STEG Official Site].

1.1.4. Activities

The principal STEG's objective is to provide the national market in electric energy and gas, to meet the needs for the whole of its customers (residential, industrial, tertiary...) [STEG Official Site].

To achieve objectives, the company executes a set of activities:

- Generation of electricity starting from various sources (thermal, hydraulics, wind mill...).
- Transmission of electricity: The management and the development of the high voltage grid (overhead lines, underground cables and substations).
- Distribution of electricity: the management and the development of the Medium and the Low voltage grid (overhead lines, underground cables and substations).
- The development and land distribution of natural gas: The management of the gas network infrastructure.
- Production of the LPG (Liquefied Petroleum gas).

1.1.5. STEG's History

Just before the independence, the electrical industry was managed by seven different companies (dealers) charged of supplying electricity to principal regions of our country, with a working installed capacity nearly 100 MW and a generated energy of about 240 GWH.

By the decree 1962 - 8 of April 3th, 1962 and aiming to harmonize the electrical and gas sector, the Tunisian state decides to nationalize the generation, transition and distribution of electricity and gas, and to entrust these activities to a public establishment, in a commercial and industrial matter, named "STEG" (Tunisian Company of Electricity and Gas).

[2] Liquefied petroleum gas

Confronted with difficulties, suitable for a young country in the process of construction and whose energy resources are, in addition, extremely limited, the STEG was called to take up a lot of challenges in order to reach its first aim: **Electrifying the country and inter-connecting the networks [STEG official site].**

According to [Chaabani, 2009], STEG has known five main periods in its whole life cycle,

1. The 60’s period: Electrifying the country and inter-connecting the networks.
   A period characterized by the establishment of the company and the setting up of the baseline framework. It was the first steps in electricity democratization and the implantation of new electric infrastructure.
2. The 70’s Period: Technical Mastery & Expertise
   to improve the security of the electricity grid and to cope with a high demand, STEG has opted for the widespread introduction of gas turbines.
   In addition, to ensure the continuous development of staff skills, STEG has opted for the creation of several centers (The training and improvement center of Khledia , testing and measure center and general technical center)
   Similarly, the gas business was making its debut in 1972.
3. The 80's Period: Saving energy & Optimal management
   the introduction of steam turbines (better performance)
   the realization of two interconnection lines with Algeria and the transverse line linking Sousse with Tajerouine .
   In 1982, construction of the pipeline connecting Algeria to Europe via Tunisia.
4. The 90's Period. Quality Control & environmental concern
   The establishment of a quality system based on ISO 9000's standards family
   The respect for the environment by introducing a step Sousse Combined Cycle (with natural gas) and the integration of wind technology (Central Sidi Daoued 20MW)
5. The 2000s period: Market Opening & Maturity stage.
   * / new entrants in the electric generation with the establishment of two independent producers. Independent producers have become operators in the domestic market with a total installed capacity of 500 MW.
   * / Tunisia signed in December 2003, along with Algeria and Morocco a Memorandum of Understanding with the European Commission for the creation of a regional electricity market for integration in the internal market EU.
   * / The Barcelona Declaration on the establishment of a free trade area on Energy from 2010.

The sixth period, which was posterior to Chaabanie’s study, is:

6. The post revolution period: Energetic challenge and Financial balance.
   The post revolution period is a transitional period which still lasts. The alternation of governments and the lack of vision are the main problems added to a growing energy demand and delicate financial balance. Bills emphasizing on electric generation from renewable resources and tendency towards electric market's liberalization.

1.1.6. STEG organization chart

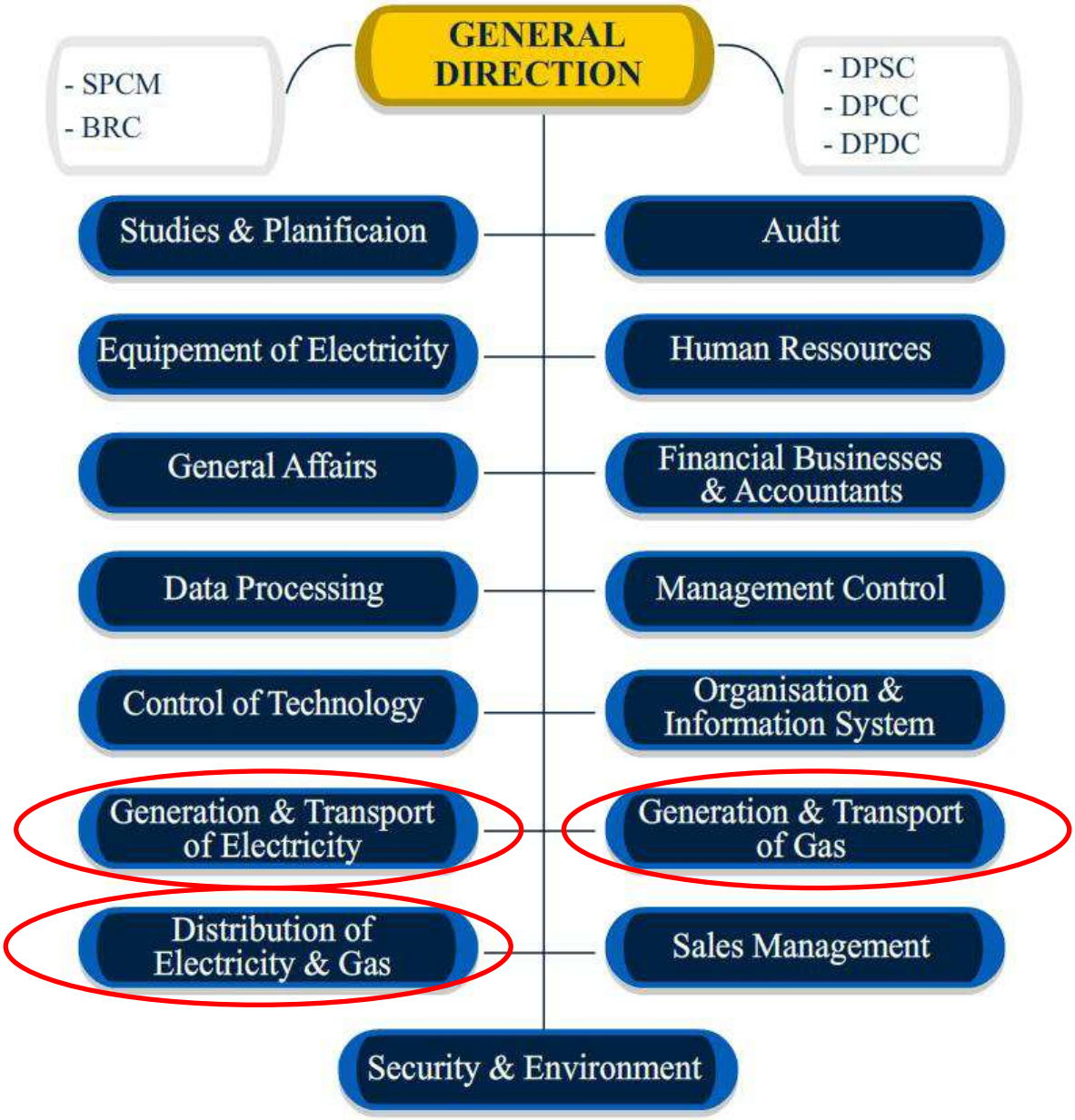


Figure 1.1 STEG's organization chart

The three circled departments are involved in the core competence of STEG:

- Generation and Transport of Gas
- Distribution of Electricity and Gas
- Generation and Transmission of Electricity (DPTE[3])

[3] « Direction de Production et de Transport d'Electricité »

The last one, DPTE, is charged of

- Management of generation's Means
- Management of transmission's means (DGMTE[4])
- Monitoring of the electrical system
- Acquirement of Generation electricity technologies
- Acquirement of Transmission electricity technologies

The DGMTE is the direction responsible for the management of the transmission assets in order to insure the availability of electricity and reliability of the network.

The DGMTE (Direction of management of transmission's means) deals with transmission's physical assets and it's charged of operating, maintaining, refurbishments and decommissioning of transmission assets. It also participates to the elaboration of tender specifications of transmission equipments.

The responsibility is subdivided according to the geographic spread of assets, The Tunisian territory is divided into five regions:

- Tunis region
- North-east region
- North-West region
- Central region
- South region

Every region is divided into two units and the subdivision is also made according to geographic considerations.

The context of this study will be within one of those units: The Unit of electricity transmission of North area of Tunis or simply BTN, This unit is charged of the maintenance of transmission assets in the north area of the great-Tunis region.

1.2. Electricity Transmission Maintenance Unit

1.2.1. Mission of the Electricity Transmission Maintenance Unit

An ETMU[5] is a functional unit that's directly involved in the management of transmission physical assets, that are contained in a limited geographic area.

Actually, the monitoring of the whole electric system is insured by another department (The national dispatching); in addition, almost all the transmission substations are remote-controlled also by other departments (two regional remote-control centers).

[4] « Direction de Gestion de Moyens de Transports »

[5] Base de transport d'électricité (Transmission electricity bases)

Despite the Transmissions maintenance units are in direct physical touch with all transmission equipments, they are not responsible of assets operating.

Their main tasks are:

- Controlling the condition of physical assets
- Insuring the first level of maintenance for all the assets
- Insuring advanced level of maintenance for :
    - High voltage Overhead lines
    - High voltage Underground cables
    - Transformers, autotransformers and
    - Substation buildings, walls, fences, enclosures
    - Protection and earthing systems
- Communicate claims to the specialized units in case of equipments that aren't maintained by the unit.
- Technical validation of new transmission assets
- Renewal of transmission plant system
- Participate to the establishment of technical specifications of new tenders to the acquirement of new transmission plants.

1.2.2. Organizational chart of ETMU

The organizational chart is built based on the different maintenance activities executed by the unit.

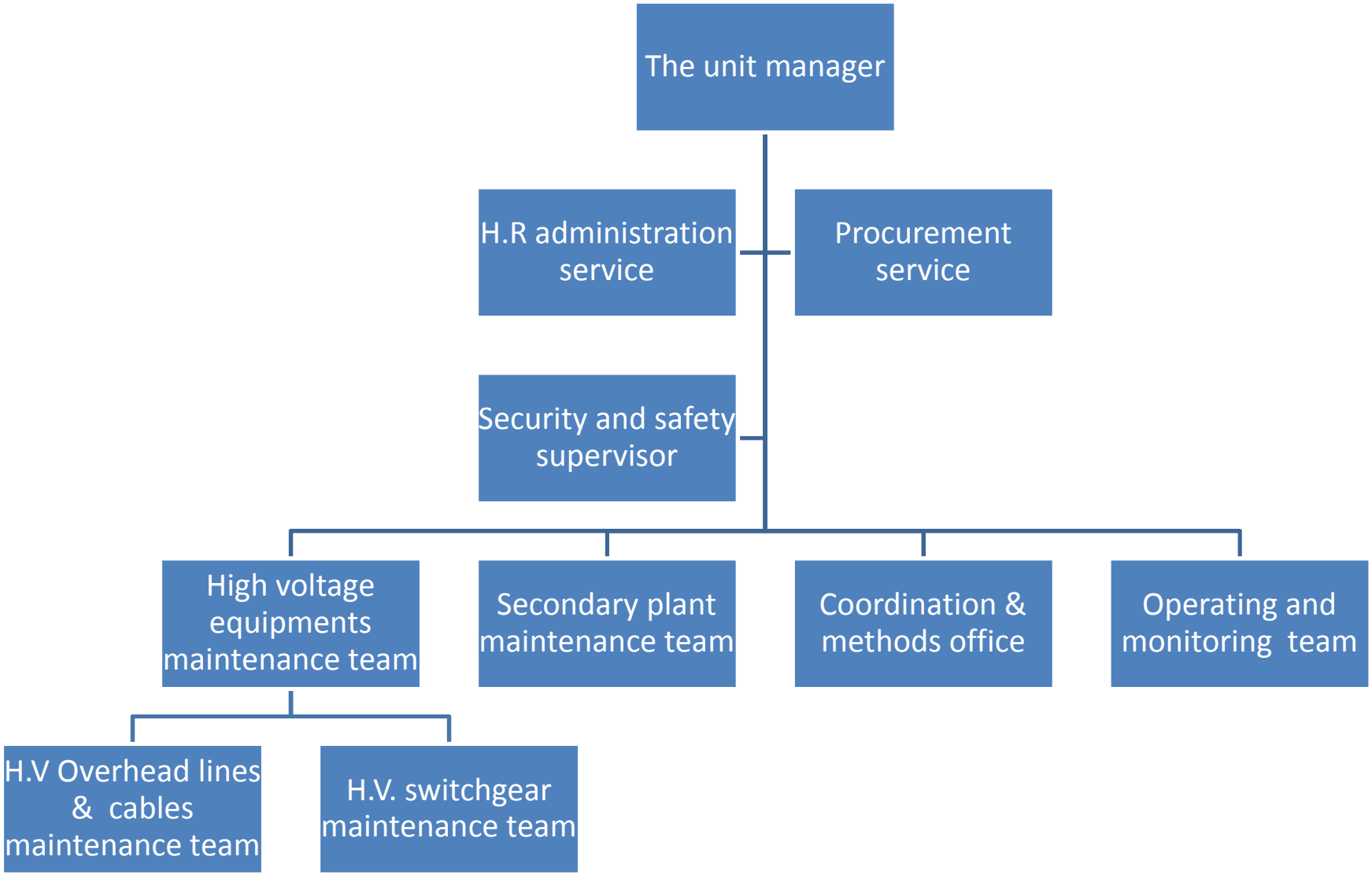


Figure 1.2 the organizational chart of ETMU

1.2.2.1. The Unit Manager:

He's the highest authority in the unit and he's involved in the management of the maintenance process.

1.2.2.2. High voltage equipments maintenance teams:

Teams charged of maintaining high voltages devices. This sort of transmission equipments is located into transmission substation or outside them such as overhead lines or cables. Thus this entity is also subdivided into:

- H.V Overhead lines & cables maintenance team: charged of maintaining of transmission connections
- H.V. switchgear maintenance team that are dealing with transformers, disconnectors, circuit breaker, transformer….

1.2.2.3. Secondary plant maintenance teams

Teams that are involved in the maintenance of control system plant (secondary plant)

1.2.2.4. Coordination & methods office

The office is responsible for the coordination and planning of maintenance tasks. In addition it's charged of managing and maintaining the CMM. Thus, it's supposed to establish and to maintain the data base of the unit.

1.2.2.5. Operating and monitoring team teams

Teams responsible for the first maintenance level into the substations. They have to assess assets condition, claim in case of problems, insuring consignation and security tasks before and after maintenance operation....

1.2.2.6. Security and safety supervisor

He controls the rigorous appliance and respect of security and safety standards

1.2.2.7. H.R administration service

Administrate all activities related to the unit employee

1.2.2.8. Procurement activities service

Administrate all procurement activities related to material resources

1.3. The problematic

STEG is 52 years old, and since 1952 until now, several things has changed and therefore, the company's strategy also has changed. Nowadays, STEG's environment is living huge upheavals and the company is under the pressure of several constraints (politic, economic, social, so forth....)

In addition, being a vertically integrated company, STEG has about six strategic business units to manage. As consequence, it should adopt adequate strategies that vary from one field to another.

The Question that stems; what would be the adequate strategy for dealing with the electric transmission market?

Timothy Devinney[6] quotes: “Corporate consultants tell us that a key driver of success is having a clear vision for the corporation and being able to execute these at all levels.”

“All level” refers obviously to the strategic level but also to the tactical level and the operational level Where ETMU acts.
As consequence, while monitoring and maintaining electric transmission equipments, ETMU aims to execute the STEG’s plan and to fulfil the corporation’s objectives.

Generally, corporation objectives are financially oriented. Conversely, ETMU addresses mainly technical issues. The dilemma is how to reach the best trade off between technical and financial concerns? How the “line of sight” between organizational strategy and the “day-to-day" activities of ETMU will be established?

Does any sought added value could be extracted from the equipments and activities management of the ETMU?

At this stage, what would be this management framework that shall deal with maintenance activities and a wide spread asset portfolio?

How the new edited asset management specification, which is ISO 55001:2014, will comply with the ETMU’s case and How the “Top down” STEG’s aspirations will align with the “bottom up” ETMU's realities?

Finally, does the implementation of this management framework is feasible for ETMU?

That is what this study will try to answer.

[6] Faculty Member of The University of Leeds, Leeds University Business School,

Chapter 2 :

Electric Power Transmission

2.1. Electric Power Delivery Process

Actually, the electric power delivery process is subdivided into three sub processes:

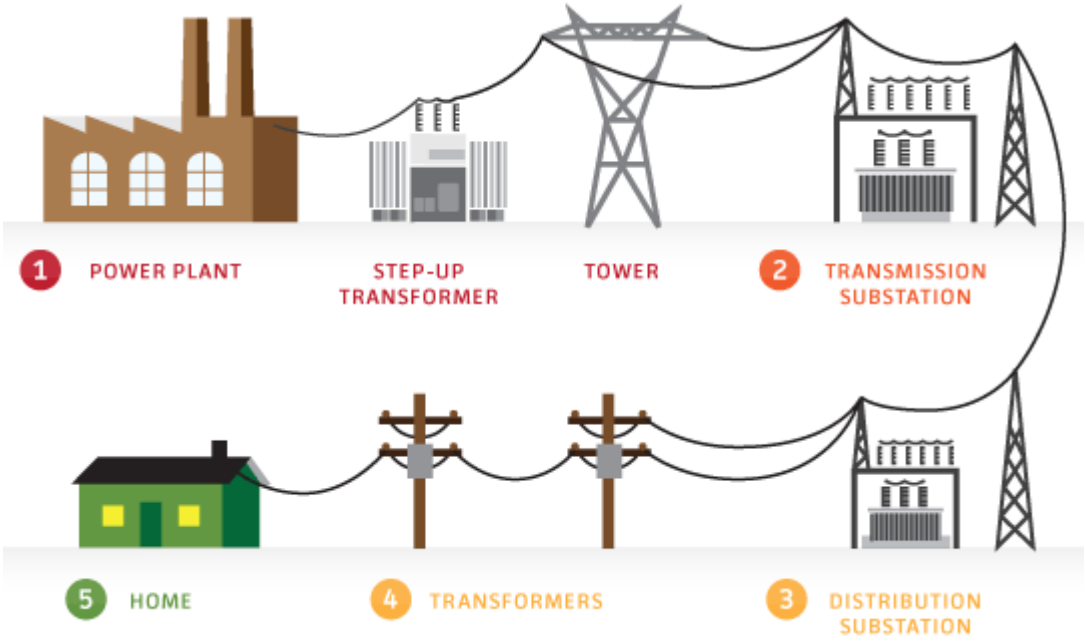


Figure 2.1: Energy Delivery -- Getting Power from the Plant to Your Home 7

- The first stage is Electric Power generation: it is the process of producing electricity from other sources of primary energy. Power plants generate electricity (in the range of 10-20 kV), send it through a step-up transformer, which raises the voltage level and sends the electricity to transmission lines.
- The second stage is the Electricity Transmission: it's the process of the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centres. The stepping up of the voltage allows the efficient transfer of energy over long distances.
  Generally when we are talking about transmission process, it means that we are dealing with a voltages range above 50kV.
  Electric power is transmitted by overhead lines or underground cables and the network of lines used to do this is called the grid, or high voltage transmission network.
  From the grid, the electricity is converted by transformers in the distribution network, stepping the power down to medium voltages (below 50 kV)
- The third stage is Electricity Distribution: it's the process of carrying electricity from the transmission system and delivers it to consumers. Electric energy, transmitted

[7] http://www.cpsenergy.com/Services/Generate_Deliver_Energy/Energy_Delivery/

through the gird, end up at the transmission substation. Transformers step down the electricity's voltage to medium voltage (below 50kV) and send it to distribution substation where eclectic power is dispatched through smaller distribution lines and make its way to specific residential and commercial districts throughout the service area.

The scope of this study is limited into the electric transmission sector. The management system, that I'm trying to carry out, is dealing with the operating and maintenance of transmission assets.

In the following, I'll introduce this activity and try to give a clearest big picture about this field.

2.2. Electric Power Transmission

Electric power transmission (Wikipedia) is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers.

Since the first steps of the emerging of electricity industry, the most important issue was: How could we manage to transfer electric power from the production point to the demanding area?
Except opting for the ubiquity of electricity production points, the best solution was the use of transmission and distribution networks.

According to technical and economic reasons, current transmission network systems are using almost the same design framework.

The network system, or simply the "gird", is generally modelled as a set of nodes joined by connectors [Crisp, 2004].

Figure 2.2: The "gird" is modelled as a set of nodes joined by connectors

Nodes are representing Transmission substations. The main role of a transmission substation is to set up or to set down voltages by means of transformer, thus electric power is transferred to the transmission grid or, in the second case, to the distribution grid.

Connectors could be overhead transmission lines and underground cables. They represent the highways of electric energy.

Bearing in mind that electricity couldn't be stocked in sufficient quantities comparing to the demand yet. This fact leads to incorporate a high degree of redundancy [Crisp, 2004] and electricity flows are managed dynamically, which imposes a huge flexibility of the grid and the insertion of a broad variety of transmission assets.

According to what mentioned above, the flexibility is reached by the integration of switchgears at either end of an overhead transmission line or underground cable. Switchgear includes many transmission equipments such as Circuit breakers, Disconnectors, Current transformer, Voltage transformer...Moreover, to protect, monitor and operate the system we use control circuits, protection relays...

2.3. Transmission equipments

According to [Crisp, 2004], equipments in the transmission network system are subdivided into:

- Lines and cables:
    - Overhead power line: [Wikipedia] a structure used in electric power transmission along large distances. It consists of one or more conductors (common multiples of three) suspended by towers or utility poles. Since most of the insulation is provided by air and insulators, overhead power lines are generally the lowest-cost method of power transmission for large quantities of electric energy.
    - Cables: [Wikipedia] a power cable is an assembly of one or more electrical conductors, usually held together with an overall sheath. The assembly is used for transmission of electrical power. Power cables may be installed as permanent wiring within buildings, buried in the ground, run overhead, or exposed.
- Substation equipments : we find two categories:
    - Primary plant: A switchgear comprising
        - Circuit breakers, used for switching and protection
        - Disconnectors, used for disconnecting and earthing circuit
        - Transformers or autotransformer used to convert energy from one voltage to another
        - Reactors and capacitors provide reactive control to maintain voltage in the network within acceptable limits.

        - Measurement devices such as voltage transformer (VT) and current transformer (CT)
    - Secondary plant: comprising
        - Control circuits (associated to the switchgear)
        - Protection relays(associated to the switchgear)
        - Communication equipment (associated to the switchgear)
        - Backup power supply
    - Infrastructure assets: building ,fences, earth mats and bus bar

Transmission assets are generally described as capital intensive, robust, long-lived and not easily relocated [Crisp, 2004].

They are managed and maintained by electricity companies such as STEG (the Tunisian Company of electricity and Gas) in Tunisia.

2.4. Electricity Transmission business

In electrical power business, a **transmission system operator** (**TSO**) is an operator that transmits electrical power from generation plants over the electrical grid to regional or local electricity distribution operators. [Wikipedia]

As described previously, transmission equipments are capital intensive. They are a costly establishing infrastructure and that's why TSO are usually a natural monopoly.

Historically, transmission and distribution lines were owned by the same company, but over the last decades, many countries have introduced market reforms that have led to the separation of the electricity transmission business from the distribution business. [Wikipedia]

Currently, worldwide, we can find different sorts of company acting within this sector.

[Crisp, 2004] has distinguished:

- **The Stand-alone organizations:** for which electricity transmission is the core activity.
- **The Vertically integrated structure:** that deal with generation and distribution or with either generation or distribution.

The electricity industry has known many changes in its structure. Historically the electricity industry was viewed as an asset of strategic importance to the country, and best managed as a single entity [Crisp, 2004]. This tendency had changed with the appearance of a new theory which was encouraging markets competitiveness as the way that would lead to an improvement in efficiency of the electricity industry [Crisp, 2004].

As a consequence, In addition to the safe and reliable delivery of electricity, Regulators, policymakers and the industry began to focus their attention on ways to improve economic efficiency, increase productivity and reduce costs through a seemingly endless series of reforms [Fages and al, 2012].

The early reforms typically involved the complete de-integration of utilities into different function [Crisp, 2004]. Typically the electricity reform process has seen a move from vertically integrated, publicly owned utilities towards structures that separate the different functions, particularly generation separated from the "wires businesses" of transmission and distribution [Crisp, 2004].

The strategic tendency according to [Fages and al, 2012] is:

- To enhance transmission and interconnection facilities with neighbouring systems in order to pool energy resources. For example the concept of the super grid[8]
- To participate in regional organisations to buy and sell power, and to administer transmission, dispatch and scheduling of a variety of energy products
- To reduce the barriers to entry by requiring non-discriminatory treatment among transmission users, and prohibiting affiliate abuse
- To unbundle certain utility services, in some cases, regulators required the divestiture of generation or transmission facilities
- To evolve their classic topologies to accommodate distributed generation[9].
- to develop a "smart grid"10

Despite that competition principals has been spread easily throughout the generation and retails sectors. The transmission one remains generally perceived as "Natural Monopoly" that's totally converse to competitiveness values.

To avoid any abuse or discrimination, the transmission sector is usually treated as a regulated monopoly. Under regulation, the main transmission companies' issues will be:

- How to maximise short-term efficiency (scheduling, dispatching and selling energy)? This will allow the achievement of a reasonable rate of return on investment and the recovery of operation and maintenance costs.
- As well as long-term efficiency (building new or retiring old transmission facilities) [Fages and al, 2012]

[8] *A super grid is a wide area transmission network that makes it possible to trade high volumes of electricity across great distances. It is sometimes also referred to as a "mega grid".*

[9] *Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy, distributed energy or district energy, generates electricity from many small energy sources. [Wikipedia, 2014]*

[10] *A smart grid is a modernized electrical grid that uses analogue[1] or digital information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. [Wikipedia, 2014]*

Chapter 3:

STEG’s strategy within the electricity transmission market

3.1. Electricity sector in Tunisia

In the following paragraph, the majority of data are extracted from the Wuppertal institute report titled “Etude Stratégique du Mix Energétique pour la Production d’Electricité en Tunisie » that could be translated as: Strategic study of the energy mix for electric production in Tunisia.

The electric sector in Tunisia is managed by the minister of industry and technology (MIT) . In order to carry out its policy in the electric sector, The MIT has under his tutorship the Tunisian Company of Electricity and Gas (STEG).

STEG could be presented as a public vertically integrated company which has as a mission the delivery of electric power, which means the generation, transmission and distribution of electricity.

Historically, just after the independence, the electric sector had been managed by eight companies. Since 1962, they had been nationalized by the Tunisian government and the Tunisian company of electricity and gas (STEG) was created.

At that moment STEG was established as a vertically integrated company, it was a monopole which has as a mission the production and the delivery of electricity in Tunisia.

Since 1996 and according to the law decree 96-27 of the first April 1996, the monopole statue in power generation was cancelled and private investors could obtain a licence allowing them to produce electricity and sell it exclusively to STEG.

Since 1997, STEG’s financial performances were really affected by the dramatically risen of crude oil's price, that has a systemically impact on the Natural Gas price.

STEG had become a burden to the government budget. Furthermore, Being a public company, funders needs the government guaranties in order to attribute any loan to STEG. Opening the production market to competitiveness was perceived as way to alleviate this constraint.

The two main experiences were:

1. The Independent power producer of Rades or (Carthage Power Company) which had generated during 2012 about 3100 GWh (18.4% of the total generated energy)
2. The Independent power producer of EL Bibane which can raise 3% of the total generated energy

We can also mention the existence of a multitude of electric auto-producer (about 13 in 2008), they mainly produce electricity for their own use and the surplus is evacuated through the national grid (a production way commonly called Cogeneration). However the total participation of these producers remains extremely insubstantial and was estimated about 63 GWh during 2012 which represents 0.4% of the total generated energy.

Regulation of electricity generation: The current regulatory framework of electricity generation allows the establishment of independent producers, all combined energy sources, on the basis of a tender after which an agreement can be negotiated with the lowest bidder.

However, some difficulties remain in very specific cases, such as:

- The case where the energy source belongs to a single private person. In this case, the tendering process is difficult to apply.
  It's the case of fatal gas projects (such gases are a by-product of the production of fossil fuels) and cogeneration (where the residual steam a process also belongs to a single private person).
- The other case is that of a source of energy for which, following a call bids, the price of the lowest bidder is higher than acceptable prices for STEG or Tunisian society as a whole.
  This is typically the case for wind projects. Actually, the STEG procedure's, while is buying this kind of energy, is based on the avoided cost for it, the cost of fuel saved. This cost seems to be below the rates that ensure satisfactory returns for independent investors in wind generation.

According to a study done by the ANME (The national agency for energy conservation) the technical- economical potential of cogeneration in Tunisia is estimated about 600MW (430MW in the industrial sector) which is more than installed power of the IPP of Rades.

On another hand, Since the 90's, the Tunisian government, via the ANME, has given a great importance to renewable energies and he has proposed many financial and regulatory incitements to investors in this sectors

Recently, a law proposition was presented to Constitutional council about the production of electricity from renewable energies.

This law is subdivides on four parts

- The establishing of an electric national plan, with a main mission the enhancement of electricity generation from renewable energies
- The encouragement of private investment in this sector.
- The enabling and expansion of auto-production concept especially for the own consumption of localities and companies.
- The regulation of electricity exportation

From the downstream side, pricing regulation remains a governmental competency; The Minister of industry has the authority of fixing the selling prices of electricity for the consumers. Although, pricing policy depends of gross oil courts, gas prices and some other economical factors, it remains also a political decision.

Clients are distinguished by the voltage level of supplying, according to the last activities reports [STEG, 2012]

Voltage	2010		2011		2012		Tendency 11/10	Tendency 12/11
High voltage	1293	9,9%	1163	9,0%	1289	9,1%	-10,1%	10,8%
Medium voltage	6052	46,5%	5986	46,1%	6397	45,3%	-1,1%	6,9%
Low voltage	5670	43,6%	5813	44,8%	6379	45,2%	2,5%	9,7%
Exportation	0	0,0%	14	0,1%	46	0,3%		228,6%
General Total	13015		12976		14111		-0,3%	8,7%

Table 3 1: Electricity Sales evolution [STEG; 2012]

Just about 10% are directly sold through the High voltage grid; the rest is transferred to the distribution network. The total consumption had stagnated during 2011 and risen during 2012. The curve of electricity demand would have the same rising tendency for the next twenty years [Wuppertal Institute Report, 2012].

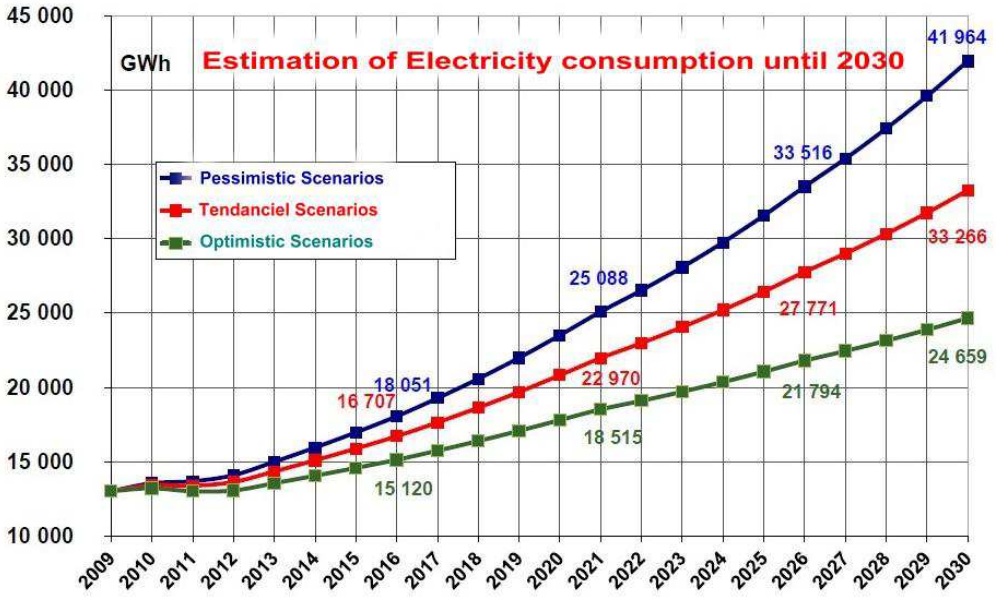


Figure 3.1: Estimation of electricity consumption until 2030

To summarize, many steps has been taken toward the liberation of the electric generation market. However, the transmission and distribution sectors remain under the STEG monopole.

Recently, the last and controversial energetic law project about renewable energy could be considered as an important milestone that may shake up the Tunisian electricity market. In fact this law and some subsequent projects, such as TUNNUR project, has an important impact even on the electric transmission market.

From the downstream side, electricity demand would have a constant growth during the next twenty years and the electric infrastructure has to follow this growth and manage this constraints.

Worldwide, the electricity market, is living a period of upheaval. Changes in regulation, market operation, industry structure, economic and social situation. This context has lead, in many countries, to the privatization, liberalization and associated deregulation of utilities and electricity market and particularly the transmission one.

Even though, it isn't totally the case in Tunisia, however the current tendency indicates that we will not be the exception. The liberalisation of the generation market was already done and the next energy laws will encourage private investors.

The entry of independent private producer (IPP) will induce new constraints for transmission sector, new regulation etc...

Moreover, one axiom of the famous 2014's energy law will deal with electricity exportation, an aspect which obviously will have a deep impact on the transmission sector.

3.2. Transmission Sector in Tunisia

In order to respond to the growing demand of energy in Tunisia and ensure the bulk transfer of electrical energy through the country, STEG had intensively invested in the extension and upgrading of the grid(143 Billion of Dinars during 2012).

According to [Wuppertal Institute Report, 2012], in 2008, the average growth of transmission grid is about 237.7 km per year. In 2012, the total length of our national grid has reached 5970 km. 2821 Km for 225Kv transmission lines, 1883km for 150Kv lines and 1266 km for 90Kv lines.

The National network is interconnected to the neighbouring countries in the context of the Mediterranean Grid; Therefore the Tunisian network is connected to the European grid via Algeria and Morocco. The Tunisian Grid is also connected to the Libyan’s one and it is projected to extend this connection in order to reach Egypt, Jordania and Syria.

Another ambitious project targets to connect Tunisia to Italy. The using of a HVDC sub marine cable with an energetic capacity of 1000MW would allow the exportation of 7TWh per year.

The existed situation allow more flexibility in managing the existent power generation park, facilitates the integration of new power plants with higher capacity and enhance technical and economical development of renewable electricity generation. Following the STEG’s vision, in few years we will be able to talk about the Mediterranean market.

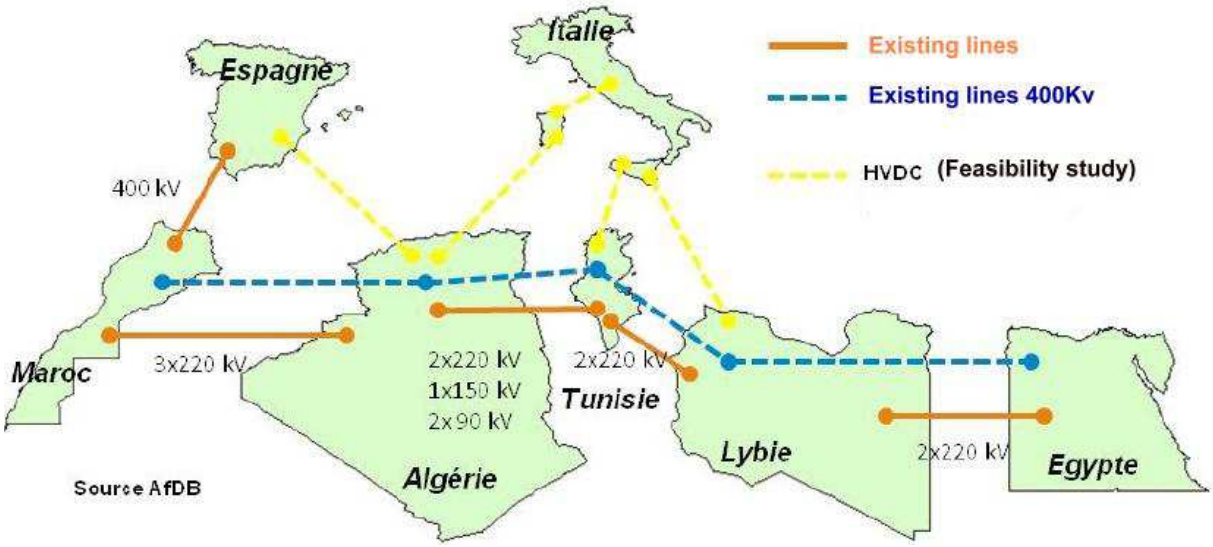


Figure 3.2: Mediterranean interconnection (Existing and projected)

Thus, the Tunisian TSO (STEG) will have new suppliers, new customers, a harder economic and social context but the same (or even higher) requested degree of safety, reliability and the best economic efficiency. And Although, Transmission sector remains a public Natural Monopole, the question will be:

How STEG, as a main actor of the transmission sector, will deal with those changes? What will be its strategy? And what will be the impact of the chosen strategy on the tactical and operational level?

3.3. STEG's strategy within transmission sector

3.3.1. Transmission as a STEG's Strategic business unit

As it was mentioned previously, the mission of STEG is the delivery of electricity, Natural Gas and Liquefied petroleum gas (LPG) for the Tunisian market.

We could distinguish, according to the deliverables mentioned below and to the activity list of the company, six (06) Strategic Business units (SBU).

- Electricity generation
- Electricity transmission
- Electricity distribution and retailing
- Natural Gas transmission
- Natural Gas distribution and retailing
- LPG manufacturing

Although that no one of those SBUs is responsible for its own profitability, there is a real differentiation and separation in performing, management and assessment of those activities.

If we consider Electricity transmission,

1. It’s managed as a separate operating entity within STEG; The DGMTE (Direction of management of electricity transmission means) is the entity responsible for operating and maintaining transmission assets. However, many other directions are charged of some tasks in transmission sector, such as managing loads, conception and extension of the network...
2. STEG is a natural monopoly in this sector; it owns 100% of transmission assets.
3. STEG delivers 20 clients [STEG Report, 2012] by high voltage alternative current (90kV and above), it also exchanges electricity with Algeria and Libya via the grids interconnections, but the great part is transferred to distribution network.
4. Energy transaction can be measured as an independent entity in terms of profit and loss. However measures are available in the STEG's reports only in terms of quantities (GWh) and not in terms of costs.

The four previous points are essential to define an SBU. However, the STEG's organizational structure, do not really allows the executive managers of the DGMTE to establish an electricity transmission strategy.
In fact, planning involves the responsibility of the DEP (Studies and plans Direction); execution of new projects is relevant to the DEQ (Equipments Direction), managing loads and electricity demanding involves the responsibility of DPSE (Direction of Monitoring of electrical systems) so forth.

This aspect would contradict the assumption that transmission electricity is considered as a SUB for STEG. However, after a benchmarking, all the literature researches have shown the establishment of standalone transmission utilities such as:

- RTE the national electricity transmission system operator of France
- ELIA : Elia System Operator SA the national electricity transmission system operator of Belgium
- TenneT B.V. is the national electricity transmission system operator of the Netherlands
- National Grid plc is a British multinational electricity and gas utility company headquartered in London, United Kingdom. Its principal activities are in the United Kingdom and north-eastern United States [Wikepedia, 2014].

Thus, the assumption could be considered valid and, currently, we could consider transmission sector as a SBU for STEG. Furthermore the targeted market isn’t limited to Tunisia but boundaries could be enlarged and we will soon talk about the Mediterranean market.

The next problematic will be, what are the opportunities and threats for the STEG within this environment.

3.3.2. PESTEL analysis

Political Factor to consider

- Political stability is a real issue, Tunisia is facing crucial political changes, It is planning for national elections at the end of 2014. Energy policy and especially electricity are sensitive subjects and currently they couldn't be treated objectively;
- The main regulator is the MIT and STEG is one of its under tutorial's companies. Any STEG strategies have to be alienated to and dictated by the MIT;
- The Government emphasizes on the good monitoring and optimization of electricity production and delivery;
- The government is looking for loans to fund construction of some electrical plant , such As the power plant of Sousse and recently a Japanese loan of 346 billons dollars to fund the construction of Rades power plant;
- The proposed law about generating energy from renewable resources
    - The establishing of an electric national plan, with a main mission the enhancement of electricity generation from renewable energies;
    - The encouragement of private investment in this sector;
    - The enabling and expansion of auto-production concept especially for the own consumption of localities and companies;
    - The regulation of electricity exportation;
- Consumer protection: The Bill about lifting the subsidy on cement, Mr. Ouerfelli said that he's concerned about the purchasing power of the consumer. The middle and low class will not be affected by grant waiver, "the State will assume the role of regulator".

Economic factors to Consider

More than 97.8% of STEG power plants use Natural gas as combustible

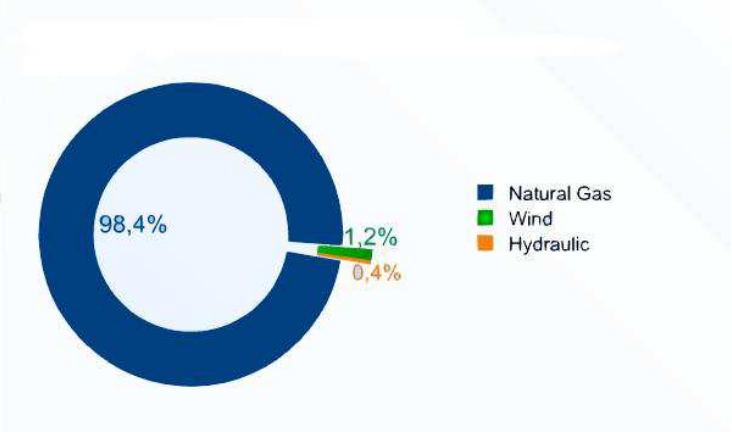


Figure3.3: STEG's Generation by fuel type [STEG official site]

Electricity generation consume about 73.15% of the national total natural gas consumption. The big issue is that recently our energy balance is in deficit, hence the resort to buying

natural gas from the international market. Certainly from the graph below there is a general pricing decline but we notice a lot of fluctuation which should be added to the depreciation of the Dinar

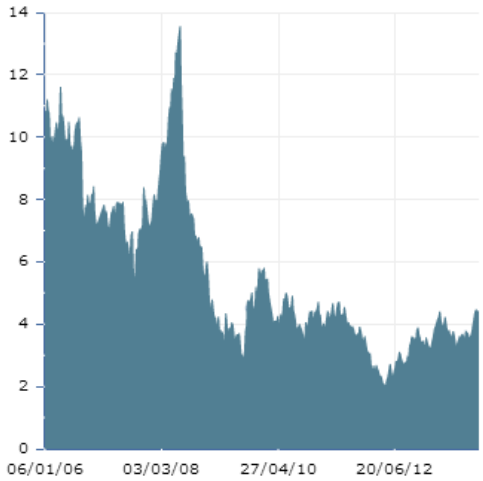


Figure 3.4: The tendency of Natural gas pricing through the last 10 years

	D'ENERGIE PRIMAIRE BILAN		
	9 mois 2012	9 mois 2013	Evol %
Unité : ktep			
RESSOURCES	**5095,5**	**4732,3**	**-7,1%**
Pétrole brut	2404	2246	-6,6%
GPL Champs	114	158	38,3%
Gaz naturel	2556	2303	-9,9%
dont:			
Redevance	697	405	-42,0%
Elect. Primaire	21	25	19,1%
DEMANDES	**6496,3**	**6541,0**	**0,7%**
Produits pétroliers	2869	2907	1,3%
Gaz naturel	3606	3608	0,1%
Elec. Primaire	21	25	19,1%
SOLDE	**-1401**	**-1809**	**29,1%**

Figure 3.5: Natural gas production and request for the two last years11

[11] MIT

Figure 3.6: Fluctuation of Euro courses during the last two years

These uncertainties induce a financial burden on the state. The expected deficit would reach 3.05 Mtoe [12] during 2014[13].

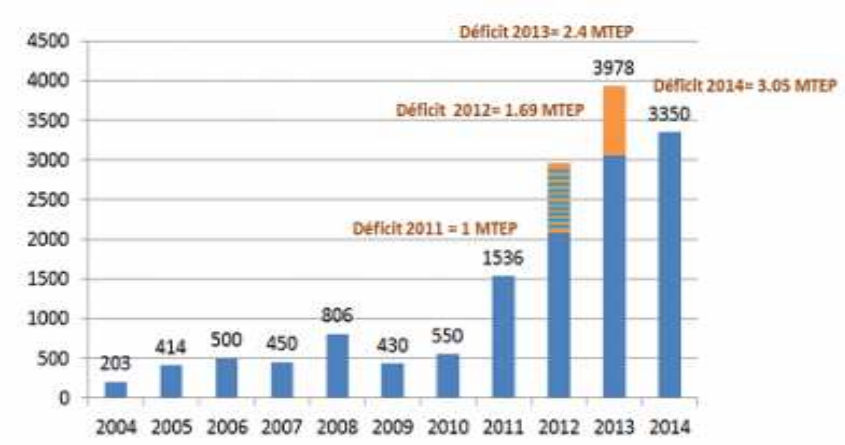


Figure3.7: The state of subsidies evolution

- **The Tunisian Solar Plan**, which in addition to the improvement of energetic efficiency , aim to enable electric generation from renewable energy in order to reach 1000MW in 2016 (16% of total generation capacity) and 4600MW in 2030(40% of total generation capacity). This governmental plan is a part of the Mediterranean solar plan and due to its energetic potential and its geographic position, Tunisia would be a hub for energy exportation to Europe [Wuppertal Institute ; 2012].

[12] Million tonne of oil equivalent (toe)

[13] MIT

Figure3.8: Expectation of power generation from renewable resources (DESERTEC Project)

DESERTEC project: it's an initiative from a non-profit organisation (Desertec Foundation) and a consortium of companies (Desertec Industrial Initiative),about the exploitation of the desert of MENA region for the production of electricity from renewable sources to supply the region and export to Europe [Wuppertal Institute ; 2012]..

Socio-cultural factors to consider:

- Electricity demand is in a continuous growth (+11% in 2013)
- Risen of life standards and customer requirements
- A lack of trust et abstention pay bills (538 million Dinars to outstanding in 2013)

Technological factors to consider:

Electricity delivery technology has reached its mature stage, Innovations are involved in the introduction of IT technologies and the dynamic management of energy demand. Tendency is moving to the establishing of the "smart Grid"[14] concept.

The increasing need for the renewable electricity production enhanced innovation in this field, and also a new concept is appearing, we are talking now about distributed generation[15] and Energy storage

[14] A smart grid is a modernized electrical grid that uses analogue or digital information and communications technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity [Wikipedia ,2014]

[15] Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy, distributed energy or district energy, generates electricity from many small energy sources. Most countries generate electricity in large centralized facilities, such as fossil fuel (coal, gas powered), nuclear, large solar power plants or hydropower plants. These plants have excellent economies of scale, but usually transmit electricity long distances and can negatively affect the environment. Distributed generation allows collection of energy from many sources and may give lower environmental impacts and improved security of supply.

Environmental factors to consider:

- Global warming affects directly electricity demand
- Carbon emission limitation's is an important constraint while utilities are choosing the power generation technology
- There is a multitude of contestation against the already erected overhead and the projected ones, Contestation are about esthetical aspect, electromagnetic pollutions...

Legal factors to consider*:*

- Law No. 96-27 of the first April 1996 and the Law 99-93 of 14 February 2002 Article 66 provide an opportunity for new entrants to invest in power generation
- Bill of renewable energy in 2014 which emphasize on investment in generating electricity from renewable energy and the regulation of its exportation.

3.3.3. Porter's Five Forces

Supplier Power: Neither the electric producers, nor the TSO have the power to drive up prices. The MIT is the main pricing regulator and it has the authority to validate any contract between STEG and any third producer.
However, transmission sector is considered as a natural monopoly, and the fact that STEG is vertically integrated company; those facts didn't give a high bargaining power to suppliers.

Buyer Power: As it was mentioned before, Buyers are

- 20 High voltage clients which had consumed about 9.13% of sold energy during 20012 [STEG Report, 2012]
- 45.33% of sold energy was consumed by medium voltage consumer (delivred through distribution network)
- 46GWh was sold to Libya

In Tunisia the distribution of electricity is also a monopoly of STEG added to the continuous growth of electricity demand; buyers didn't have any power to negotiate prices. However in this case also, the MIT is the market regulator.

Competitive Rivalry: The transmission equipments are capital intensive, STEG is a monopoly in the Tunisian market.
However, the TunNur project also aims to transmit electric energy from South of Tunisia to the UK grid, via a HVDC cable and the European grid. This project could be a serious competitor in the European market

Threat of substitution: The technology of electricity storage doesn't offer new alternatives to substitute the on-demand's generation of electricity. The production of electricity and therefore its bulk transfer remain the most effective way for managing electricity demands. Conventional power plants are still offering the best cost effective solution.
But, the rise of fossils energies prices, the increasing concerns about global warming and the ecologic awareness are leading to encouraging generation from renewable resources,

Subsequently, the appearance of distributed generation which will use particularly the distribution grid. The proliferation of this concept, the distribution grid will offer a substitute service to the one offered by the transmission network.

Threat of new entry: The high capital requirement is the main barrier to transmission market entry, However one axiom of 2014's bill is talking about regulation of the exportation of electricity, which could be interpreted as sign from government to the liberalization of the transmission market (TUNNUR project).

3.3.4. Internal analysis

3.3.4.1. Value Chain

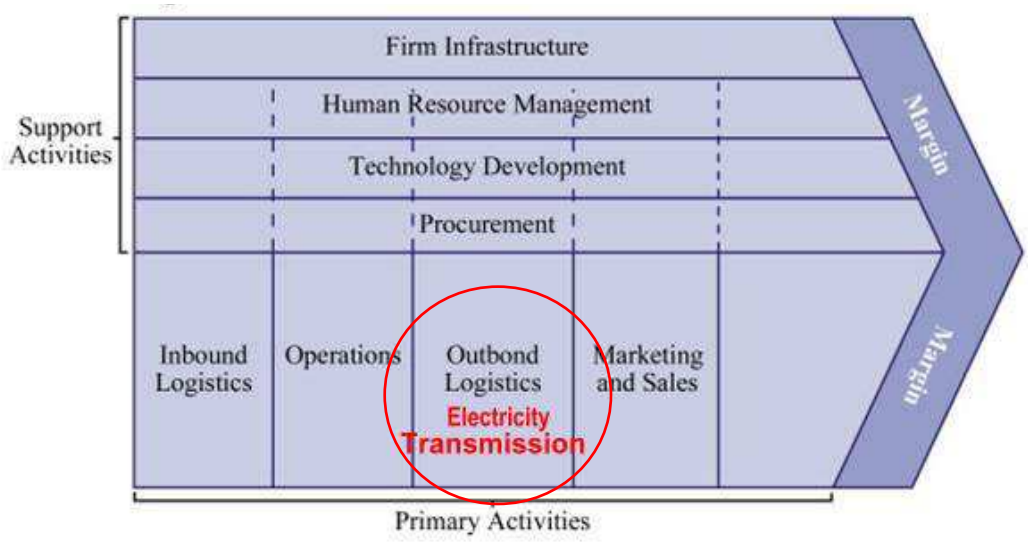


Figure 3.9: Value chain

If we consider that electricity generation as the operation activity in the STEG's value chain, electricity transmission and distribution are the outbound logistics.
The power generation market is already liberalized and the future perspectives are for more liberalization. The electricity retailing could be privatized, many privatization experiences has been lead in different countries. Even more, the problem of unpaid bills (553 million DTN according to last STEG's statistics) and the huge burden induced by this sector, privatization could be good solution.
However the transmission and distribution grids of STEG are its main competitive advantages. Moreover, this activity may be the best mean for entering in new markets. The European market precisely.

3.3.4.2. The assessment of skills and resources of the company

- The percentage of supervisory staff in businesses is about 28% , STEG count about 12506 employees in 2012 with a total l rise of 20.8%

	2010	2011	2012	Variation
Executive	2415	2621	3075	17.3%
Foreman	5477	5641	5376	-4.7%
workman	1875	2600	4562	75.5%
unavailable	507	513	507	-1.2%
	9260	10349	12506	20.8%

Table 3.2 : STEG's staff distribution

We notice that there is a real increase in employees' number, however the main category is the Workmen and it is due to the post revolution policy. This policy has induced a great burden on STEG's budget but without real added value.

- STEG has cumulated a rich knowledge during its 50 years of establishment,. Its training centre is real knowledge bank which produce a well trained promotions of foremen and workmen. STEG also invest in training program (about 3991 thousand DTN during 2012). However the average age is about 43 years and 5 months and if we notice that for foreman and workman, the retirement age is about 55 years, we deduce that in the next years we will lose a big part of our tacit knowledge.
- The net income of 2012 is -115 792 k DTN in 2012 versus -17 168 k DTN in 2011. The financial situation of the company is quite critical.
- The organisation structure is not up to date, the same structure remains since 52 years, the transmission activity is managed by different directions and coordination between them is more and more difficult due to the growth and complexity of activities.

3.3.5. SWOT matrix

Through the previous analysis we could present the below SWOT matrix.

Strengths	Weaknesses
• A rich knowledge and 52 years experience • Skilful workforce • Implanting throughout the territory • Monopoly in transmission and distribution	• Capital intensive equipments • Rigidity of the STEG's organization chart • An inappropriate rise of employee's number without real added value. • Bad financial results
Opportunities	**Threats**
• High potential in renewable energy production • interconnection with the Maghrebean & Mediterranean grid (European market) • world energetic crises and ecological concern • The liberalization of electric exportation	• Political instability • Economic crisis • The liberalization of electric exportation • New regulation • The politicized electric pricing policy • A sustainable growth in energy demand • Distributed generation

Table 3.3: SWOT matrix

3.3.6. suggested STEG's Strategy

STEG couldn't stay inside a bubble, isolated to the upheaval changes in its environment. With new challenges, opportunities and threats, there is an ineluctable need for deep changes in STEG's structures and strategies.

A benchmarking has shown that the de-regulation of electric sector and the separation between its main components is unavoidable. Consequently, the establishment of a focus strategy on the electricity transmission sector is a must.

This strategy should face many constraints such as:

The growth of energy demand and consequently the expansion of the transmission plant;

The rise use of the Renewable electric generation technologies. This sort of energy is characterized by its variability, its uncertainty and its specific geographically location. Those constraints induce a huge need for a high level of flexibility in the grid management (the introduction of Smart Grid concept).

Entry to the European market and the potential establishment of a Mediterranean Market is also considered as opportunities as well as threats. As consequence, transmission plant have to meet reliability and availability requirements to provide needed capacity into the future [BPA; 2010].

Operating, maintaining and expanding the transmission plant need a capital intensive investment and induce large expenditures. However, the economic and political uncertainties in Tunisia, added to the critical financial situation of the company makes searching for new investment funds a difficult and penalizing task.

As a result, the company should opt for a cost-conscious strategy that focus on return on assets and disciplined spending [Rijiks and al, 2010]. A strategy that emphasis on delivering both commercial and technical world performance, i.e. continuous improvement of return from transmission assets while maintaining and improving operational reliability [N Kolibas, 1998]

This statement complies with what STEG declares in its official site: “The technological choices adopted by STEG are explained by its permanent concern with finding a better compromise among reliability requirements, the availability, the control costs and the respect of the environment.”

The adopted strategy is basically constituted around the below three pillars

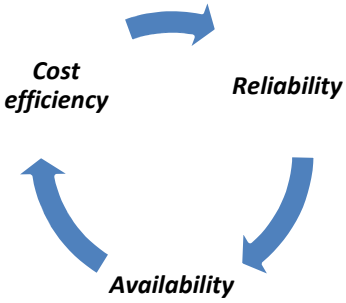


Figure 3.10: STEG’s key strategic pillars

The strategy should also be aware of environmental issues, safety, security and health care. In addition, the strategy should be aware of workforce competencies and skills and the knowledge management.

The suggested strategy, that meets all concerns enumerated below, is the adoption of Asset management.

Asset management is a corporate strategy that seeks to balance performance, cost, and risk. Achieving this balance requires the alignment of corporate goals, management decisions, and technical decisions. It also requires the corporate culture, business processes, and information systems capable of making rigorous and consistent spending decisions based on asset-level data.

The result is a multiyear investment plan that maximizes shareholder value while meeting all performance, cost, and risk constraints.

The goals of asset management are to:

- Balance cost, performance, and risk;
- Align corporate objectives with spending decisions;
- Create a multiyear asset plan based on rigorous and data-driven processes.

Chapter 4 :

Asset management

4.1. Asset Management

4.1.1. Definition of asset management

According to PAS 55, an Asset is: "*plant, machinery, property, building, vehicles and other items that have a distinct value to the organization*" [PAS 55-1:2008]

According to ISO 55000, an asset is: "an item, thing or entity that has potential or actual value to an organization"

We could distinguish five types of assets (Physical assets; Human assets; financial assets; Information assets; Intangible assets). The current study will focus on physical assets.

PAS 55 defines asset management as: "*Systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and assets systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan*"[PAS 55-1:2008]

ISO 55000 defines asset management as a coordinated activities and practices through which an organization delivers value from its assets.

CIGRE quotes that Asset management activities and practices attempt to optimally manage assets, and their associated performance, risks and expenditures over their life cycle for the purpose of achieving the required quality of service in the most cost-effective manner. [Electra N°262, 2012]

Effective implementation of asset management requires a disciplined approach which enables an organization to **maximize value** and deliver its **strategic objectives** through managing its assets over their **whole life cycles**. [PAS 55-1:2008]

According to [PAS 55-1:2008], this is achieved by:

- Determination of appropriate assets to acquire or create in the first place
- How best to operate and maintain assets
- The adoption of optimal renewal, decommissioning and/or disposal options

According to ISO 55000, the establishment of an asset management system is considered as a corporate strategic decision.

4.1.2. Benefits of asset management system

The principle benefits of optimized life cycle asset management according to [PAS55:2008] are:

- Enhanced customer satisfaction from improved performance and control of product or service delivery to the required standards;
- Improved health, safety and environmental performance
- Optimized return on investment and /or growth;

- Long-term planning, confidence and performance sustainability;
- The ability to demonstrate best value-for-money within a constrained funding regime;
- Evidence, in the form of controlled and systematic processes, to demonstrate legal, regulatory and statutory compliances;
- Improved risk management and corporate governance and a clear audit trail for the appropriateness of decision taken and their associated risks;
- Improved corporate reputation, the benefits of which may include enhanced shareholders value, improved marketability of product/ service, greater staff satisfaction and effective procurement from the supply chain;
- The ability to demonstrate that sustainable development is actively considered within the management of the assets over their life cycles.

ISO 55000 quotes that benefits of Asset management are:

- Improvement of financial performances
- Provide information for capital investment decisions
- Risk management
- Improve operational and service level
- Prove the social responsibility
- Improve the brand image
- Improve the sustainable development of the organization
- Improve the effectiveness and the efficiency

For many companies, the assets are core to the organization's purpose, such as utility networks, power generation, railway or road systems, oil and gas installations.... [PAS 55-1:2008]

In this sort of companies, business performance is closely related with the good operation and performance of its physical assets. Their success of is influenced by the stewardship of its assets and thus by its asset management system.

Delivering the best value for money in the management of physical assets is complex and involves careful consideration of the trade-offs between ,Performance, Cost and Risk Over all stages of the assets' life cycle.
There are inherent conflicting factors to manage, such as short-term versus long-term benefits, expenditure versus performance levels, planned and unplanned availability, or cost capital costs versus operating expenditures. [PAS 55-1:2008]

There are also different levels at which assets can be identified and managed- ranging from discrete equipment items or components to complex functional systems, networks, sites or diverse portfolios.

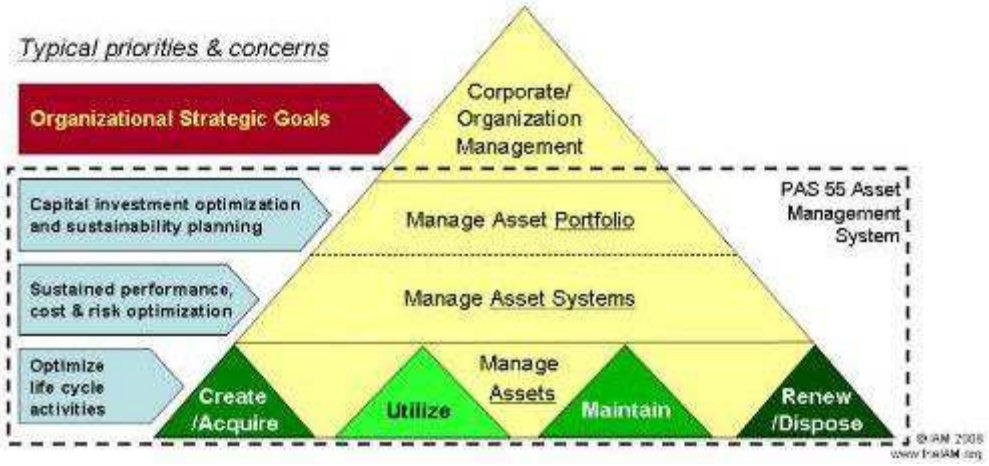


Figure 4.1: Levels of assets and their management

In summary, Asset Management involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve the organizational objectives. This balancing might need to be considered over different timeframes.
Asset Management is the art and science of making the right decisions and optimizing the delivery of value. [IAM[16], Official site[17]]

4.1.3. The structure of an asset management system

The asset management system is a tool to satisfy the corporate environment's expectations by supporting the delivery of the Organizational Strategic Plan (OSP).

The OSP is transferred to the operational level by the establishment of an asset management policy, an asset management strategy, asset management objectives and plans. These, in turn, direct the optimal combination of life cycle activities to be applied across the diverse portfolio of asset systems and assets. [PAS 55: 2008]

The asset management system emphasizes also on the performance and condition monitoring and therefore on the continual improvement approach.

This sort of feedback, given by the monitoring and continual improvement process, provides top management with reliable and accurate data from the day-to-day activities.

As consequence, sustaining the “line of sight” between different levels of management allows the alignment of the “Top down” aspirations of the organization with the “bottom up” realities and opportunities of the assets.

[16] Institute of Asset Management

[17] www theiam.org

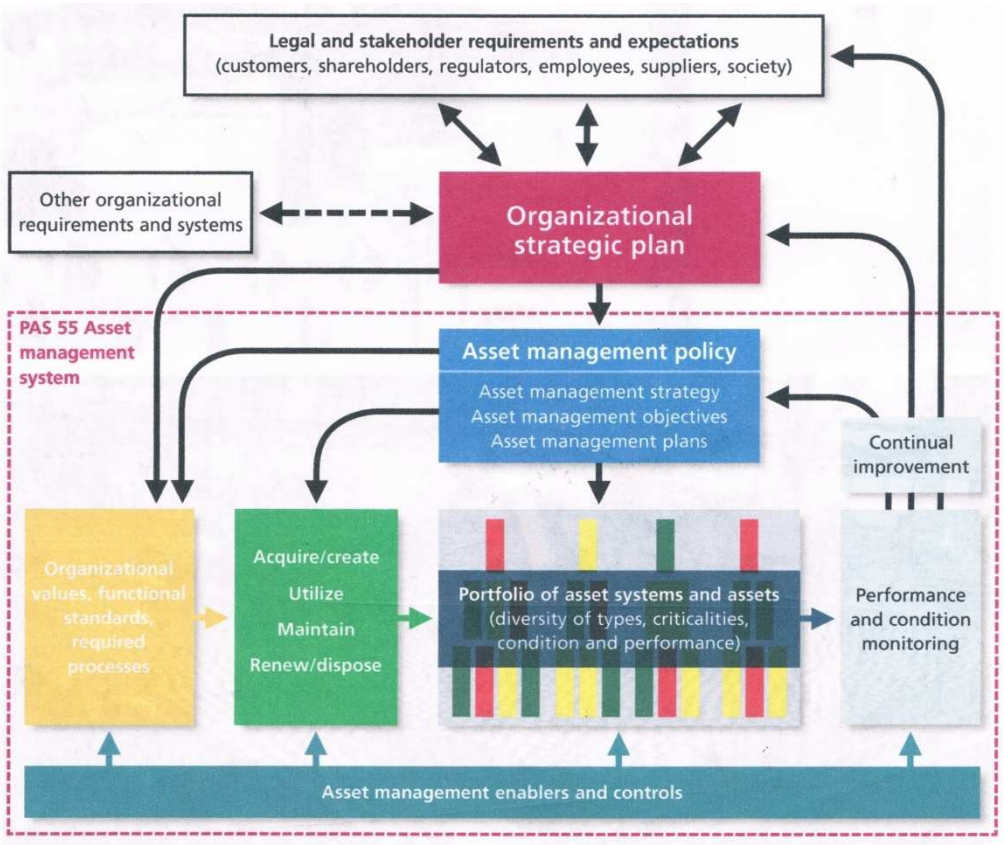


Figure 3.12: Overview of the asset management system, its relationship to the organizational strategic plan and stakeholders expectations [PAS 55:2008]

4.1.4. Asset management for the transmission utilities

For infrastructure companies, asset management is of fundamental importance for it is related to effective risk management, making investment decisions that will produce maximum return on assets, reduce losses and ensure reliability and quality in a regulated and demanding market.[Marisa; 2012]

As part of infrastructure companies, electricity transmission companies are basically operating the transmission network, so that, they are operating a set of physical assets. Each asset has its own value that makes monitoring and controlling its usage desirable, in order to achieve the core business objectives.[Soemeer;2012]

As it was mentioned at the strategic study chapters and according to CIGRE[18], the evolution of electricity utilities, through various waves of expansion, privatisation, de-regulation and re-regulation, has elevated the practice of asset management to a core focus of senior management. [E.Rijks & al, 2010]

[18] International Council on Large Electric Systems (Conseil International des Grands Réseaux Electriques)

According to the same study, the spread of risk management practices, the development of IT technologies and the tight stakeholders' requirements, pressures and scrutiny have given an impetus to asset management practices.

In this sense Asset Management is regarded as a total business concept that comprises the management of risks for the business value arising from the asset base itself (e.g. aging of the assets) and the risks arising from (in-)adequate response to changes of the environment (e.g. load growth).
The holistic Asset Management business model implies that asset management is more than maintenance management of specific types of assets; it comprises the complete asset base and all risks that can impact on the business value. Therefore Asset Management includes maintenance management aspects as well as system planning aspects. [E.Rijks;2012]

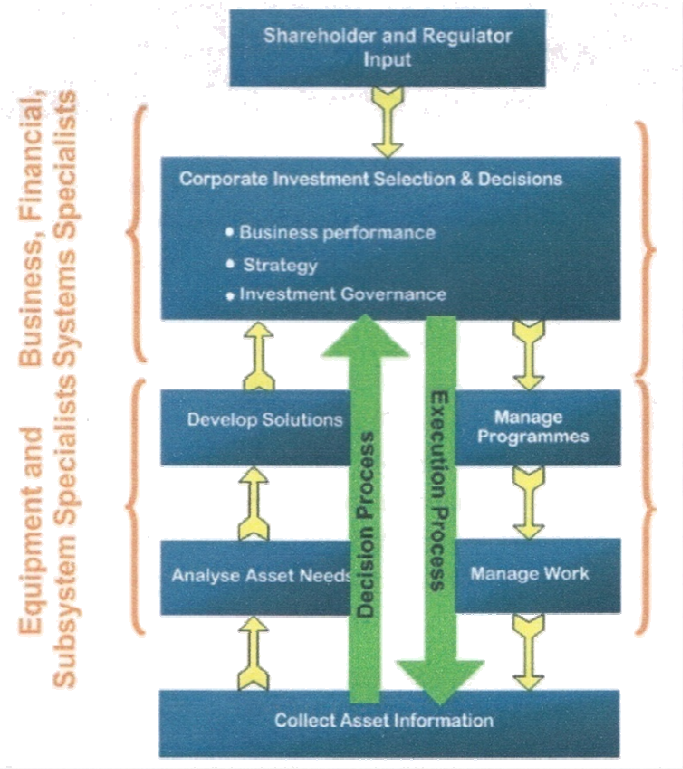


Figure 3.13: Asset management Business Process Model [E.Rijks; 2010]

The Asset management practices have been adopted over the world. For few years we have been talking and applying the PAS 55 of the British Standards Institution's (BSI). (PAS: Publicly Available Specification for the optimized management of physical assets.)

According to the official site[19], PAS 55 has proven very successful, with widespread adoption in utilities, transport, mining, process and manufacturing industries worldwide. The 2008 update (PAS 55:2008) was developed by 50 organisations from 15 industry sectors in 10 countries. The International Standards Organisation (ISO) has now accepted PAS 55 as the basis for development of the new ISO 5500X series of international standards.

[19] http://pas55.net/

A documentary research has shown that a plethora of companies over the world has adopted Asset management. Such us

- National Grid Electricity Transmission (NGET, England and Wales)
- ElectraNet Electricity Transmission, South Australia
- Hydro one Ontario Canada
- Bonne Ville Power Administration USA
- Northern Ireland Electricity
- Western Power Australia
- Victorian Electricity Transmission Network Australia
- Terna in Italy

For example, a sample of asset management objectives extracted from Asset Management Strategy of the Victorian Electricity Transmission Network:

- Create sustainable asset and network risk-profiles to underpin future performance
- Meet reliability and availability performance targets
- Improve health, safety, environment and infrastructure security performance
- Comply with codes and regulations
- Minimise life-cycle costs

What is also noticeable is the fact that the drivers that have led this company to the establishment of this system are the same for STEG.

They enumerate:

- Sustainable Network Risks – Reliability and availability expectations, maintenance of asset condition and sustainable network and asset risk profiles are driving high maintenance, refurbishment and replacement volumes
- Network Augmentation Levels – Continuing growth in demand, increasing network fault level restraints and high equipment utilization levels are increasing the levels of network augmentation
- Performance Improvements – Code compliance, and health and safety, environment and infrastructure security performance improvements
- Efficiency – Continuing efficiency demands elevated asset management practices
- Technology - Emerging viability of new technologies
- Workforce – Potential workforce skilling demands

Finally, the adoption and the establishment of an asset management system based on PAS 55: 2008 specifications or based on the new ISO 55000 standards is a must.

Despite that the establishment of such system should emanate from the top management level. The operational level, in this case represented by the Electricity Transmission Maintenance Unit, could be inspired by this concept.

4.1.5. Asset management for STEG's case

CIGRE stipulate that transmission companies are moving from a traditional management model to a modern one.
Traditionally, the transmission function was a sub-section of a larger electricity entity. Investment decisions were made based on an individual's experience, generation expansion requirements and internal planning processes. It could be said that this was intuitive process, driven by specialist engineers. [E.Rijks; 2010]

This description fits with the STEG's model. STEG is a vertically integrated company. It manages electricity market with a holistic manner. Transmission strategy stems from generation expansion policy and decisions are solely driven from technical point of view.

In the contemporary environment, a recommendation to proceed with a significant investment to replace aging assets on the basis of engineering opinion is frequently no longer adequate. However, Within STEG, the replacement decision making remains mainly a technical decision.

Nowadays, there is a move from the historic "bottom-up" drive for asset management to a "top-down" drive. That is, instead of the technical elements of a business seeking to push asset management concepts up through their organisation to improve efficiency we will now see regulators and boardrooms drive implementation for one or a combination of the following reasons[20]:

- Regulatory Compliance
- Contribution to Due Diligence
- Marketing strategy
- Competitive advantage

Conversely, STEG's decision related to established assets are mainly technical and do not have an associated economical arguments

Utility management, shareholders, regulators and utility customers want transmission companies to optimize the value of investment in assets and, as a result, business cases to justify such investment will see increasing scrutiny. [E.Rijks; 2010]

Conventional methods based on engineering judgment may be adequate for operational level asset management decision making; but quantitative and more advanced analysis are needed for tactical and strategic level. [E.Rijks; 2010]

The Asset management is interested by both technical and financial aspects. It also covers the three differentiated levels: strategic level, tactical level and operational level.

[20] http://www.assetivity.com.au/article/asset-management/what-is-iso-55000.html

According to CIGRE's study, each level has its characteristics:

Level	Time frame	Focus by relevant manager	Priorities and concerns	Goals	Reference Document
Strategic	Long term	Link company KPI with asset management policies and facilitate the approval of tolerable risk levels/criteria at the corporate level	Manage asset portfolio	Capital investment Optimization	Asset Management strategy
Tactical	Medium term	Optimizing and justifying investment decision and coordinating short and long term asset management plans and budgets	Manage asset systems	Optimization of cost and risk	Asset management objectives
Operation	Short term	Optimizing the allocation of budget in the short term and coordinating funding with service providers to maximize efficiency and benefit	Manage assets	Optimization of life cycle activities	Asset management plans

Table 3.4: Asset management level

To conclude, Asset management should be the most adequate system for managing the STEG transmission activities for all its levels of management.

4.2. Management within the context of the ETMU at STEG

4.2.1. ETMU activities

Transmission activities at STEG could be gathered into 5 main groups:

1. management of the grid (management and coordination power generation , transmission and electricity demand, as a whole and integrated system in order to answer and satisfy customers' requirements)
2. Remote operating and monitoring of the electric transmission system
3. Designing and extending of the grid according to the current and future requirement of customers
4. Maintenance and monitoring of electricity transmission physical assets
5. Refurbishment, decommissioning and dismantling of transmissions assets

Actually the ETMU[21] is mainly involved in the fourth activity. Maintenance is the core business of the unit and the maintenance process should be considered as an operational process which provide and create the primary value stream.

While the ETMU participates to the designing and expansions activities, its participation is based on its maintenance experience and feedback. It has for objective to improve the purchased assets design and guarantee the best equipments reliability and to decrease the risk of failure…

Equally, ETMU is supposed to participate to the assets refurbishment and decommissioning. It takes part to the decision making process and even to the works execution. In both cases, the ETMU participation is basing on its maintenance knowledge.

[21] electricity transmission maintenance unit

Thus the two previous activities are considered as outputs of the maintenance process. Any other activity within the unit is supposed to support or manage the maintenance process.

4.2.2. Maintenance function in the electric transmission sector

Basically, the transmission network comprises a wide variety of assets that stems from different technologies fields, and fitted together as a system to fulfil the function of electricity transmission.

Those assets are spread over large geographic areas, and so they are under several severe constraints such as operating constraints, weather constraints, pollution constraints....
Those factors added to the weariness phenomena lead to the gradually deterioration of equipments and affect the reliability factor.

As a response, the maintenance competencies are the best tool to improve asset reliability. However, maintenances activities induce increasingly costs and equipment unavailability.

The dilemma is to seek for an optimal balance between the three aspects.

According to [Asgarpoor & Doghman 1999]: Electric utilities are confronted with many challenges in this new era of competition such as rising Operation &Maintenance costs, growing demand on systems, maintaining high levels of reliability and power quality, and managing equipment aging.
Therefore, the health of equipment is of utmost importance to the industry because revenues are affected by the condition of equipment. When demand is high and equipment is in working order, substantial revenues can be realized.
On the contrary, unhealthy equipment can result in service interruption, customer dissatisfaction, loss of good will, and eventual loss of customers.

To conclude, as well as any other plants, the transmission one requires the maintenance function; moreover it needs a systemic management system that will provide the transmission companies with tools to achieve the lowest possible grid cost with acceptable technical performances. Meanwhile, this system, have to satisfy their regulators, stakeholders, and customer requirements.

4.2.3. Asset management for ETMU

For modeling the management system in the ETMU and considering the fact that maintenance is the main activity. A management framework is needed and that is focused on maintenance.

According to [Guillaume; 2009], there is a plenty of methods, approaches and tools in the maintenance field which are adopted, adjusted to the corporation business. However he noticed some issues such as:

- Lack of coherence
- Lack of prioritizing
- Lack of standards useful and applicable to any type of business

That is what pushes [Guillaume; 2009] to choose the ISO 9001:2008 standard as a framework to the maintenance management system. He argues his choice by the fact that this standard is:

- Already applicable to any business type
- Its terminology is worldwide adopted and fit with any business

However, according to the previous paragraphs, the electricity utilities are categorized as an infrastructure business and the current tendency is to opt for the establishment of an asset management system according to the British Standards Institute specifications (PAS 55:2008) or to the states of the art ISO specification's (ISO 55000).

An asset management system tries to manage assets and assets system (the systemic approach is highly important for the electric utilities context), their associated performances, risks and expenditures over their life cycle.

This management system covers the four life cycle phases of the assets (Acquiring, utilization, maintaining, and renewing or disposing) and consequently, covers the activities of ETMU.

The asset management system helps to deliver the best trade off between performance, cost and risk over all stages of assets life cycles. It tries to balance between the short term and long term considerations.
So that, it’s a tool to link the operational level to the tactical level and finally to the strategic level within the company.

The asset management system is also adjustable with other existing management system, it uses the business process approach and it bases on the PDCA approach.

The asset management system seems to be the most adequate to ETMU context, it covers the whole assets life cycle, it integrates all activities performed by the unit, and moreover it harmonizes its activities with those performed by other department and other management levels.

The following study aims to study and plan the establishment of an asset management system within the ETMU. This management system will mainly focus on maintenance activities. The scope of the asset management system will only be limited with the ETMU’s portfolio. This management system will comply with the ISO 55001 requirements.

4.3. Presentation ISO 5500X suite of standards

The three ISO Asset Management (AM) Standards have the potential to impact all organizations that have asset management responsibilities. These Standards, whilst framed on the management of physical assets, can be utilised for any asset type and by any size organization. They address the requirements for a management system (not software) for the management of assets and comprise [IIMM; 2014]:

- ISO 55000 Asset management – Overview, principles and terminology
- ISO 55001 Asset management – Management systems -Requirements
- ISO 55002 Asset management – Management systems -Guidelines for the application of ISO 55001.

ISO 55000 is an overview of what an asset management system consists of and of the terminology that is used throughout the ISO 5500X suite of standards. The basic principles of asset management are mentioned, and the benefits that such a system offers the different management levels of an organisation are briefly outlined. [Van den Honert & al; 2013]

It considers that asset management is based on four fundamentals [Sondalini; 2014]:

1. Bringing value for the organization and all its stakeholders from the use of its assets;
2. Promoting alignment across the organization to achieve organization goals;
3. Managerial leadership with commitment, along with an empowerment culture;
4. Achieving Assurance of producing required asset performance.

ISO 55001 specifies the minimum requirements to establish, implement, maintain, and improve an asset management system. These requirements are to enable parties, internal and external, to be able to measure an organisation's ability to meet legal, regulatory, and contractual requirements as well as the organisation's own requirements. [Van den Honert & al; 2013]

It details the things required to be done. It enumerates some 72 (shall) requirements with a number of sub elements. The structure of the Standard is formatted under the main headings, as follows:

- Context of the Organisation
    - Needs/Expectations of Stakeholders
    - Scope of the AM system and to which assets it will apply.
- Leadership and Commitment
    - Policy, Roles, responsibilities and authorities
- Planning
    - Risks and Opportunities
    - AM Objectives and planning to achieve them
- Support
    - Resources, awareness, competence
    - Communication
    - Information
- Operation and Control
    - Change management

    - Outsourcing
- Performance Evaluation
    - Monitoring and Review
    - Auditing
- Improvement
    - Nonconformity
    - Corrective and Preventive Action
    - Continual improvement

Using the PDCA concept, the framework of the management system could be presented as below:

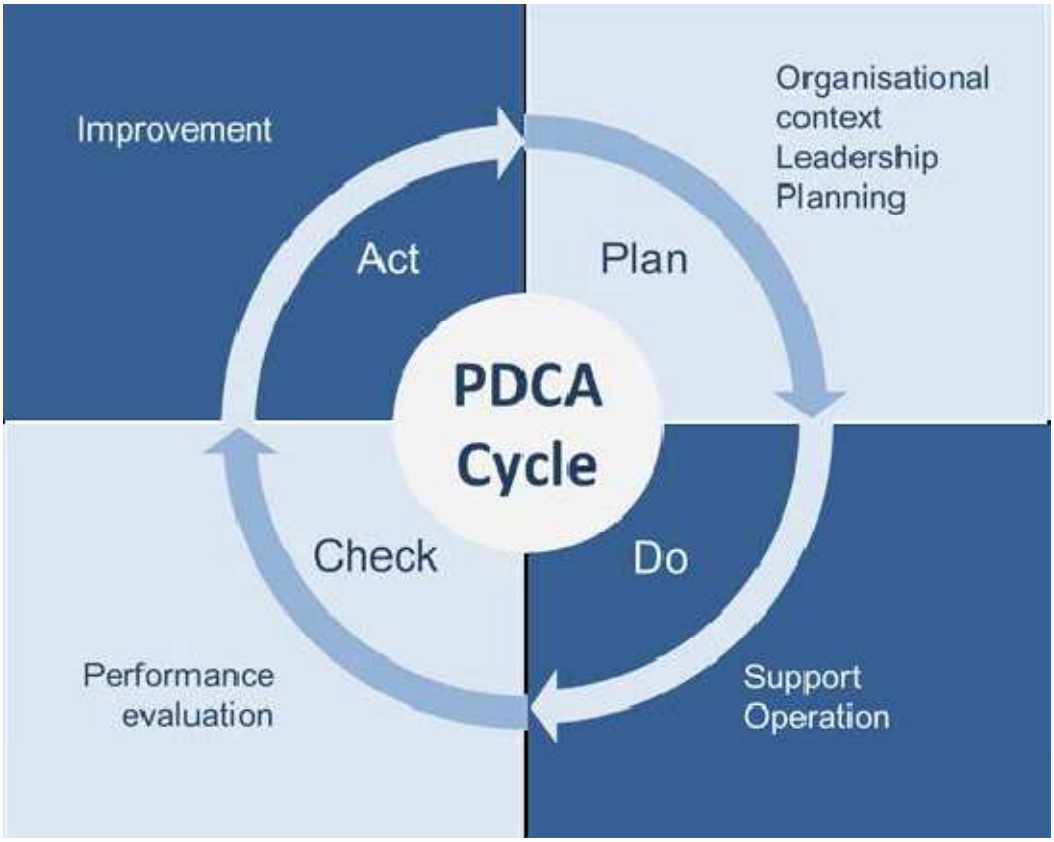


Figure 3.14: The PDCA Cycle with related ISO 55000 clauses [Botha; 2014]

The last standard of the suite, **ISO 55002**, offers guidance on how to apply an asset management system in accordance with the requirements of ISO 55001. The standard informs the reader of how to implement and maintain an asset management system at all management levels of an organisation by providing guidance of what should be done. It also gives insight into the planning, operation, and support activities that go with such a system. [Van den Honert & al; 2013]

ISO shaped the asset management system as below.

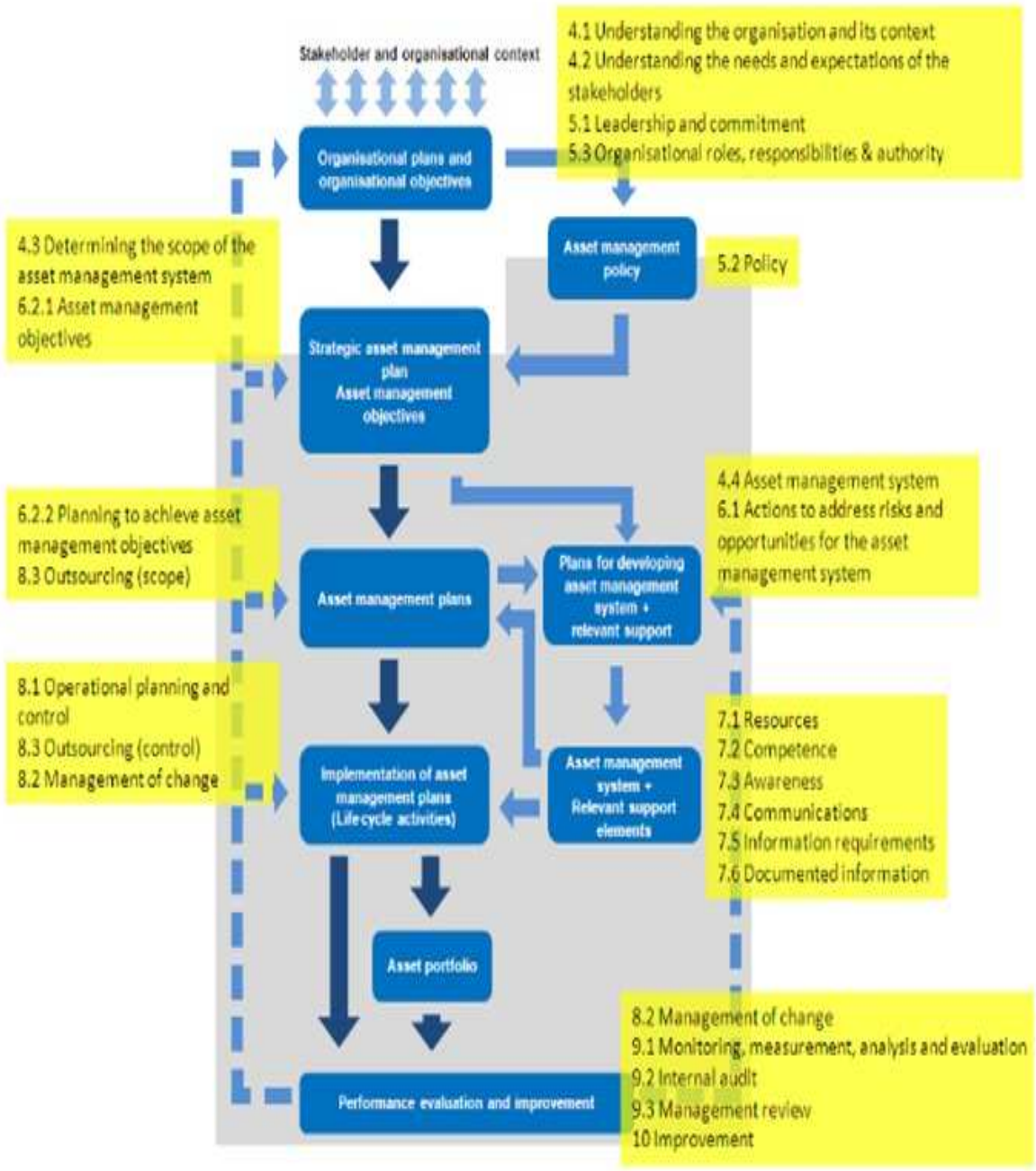


Figure 3.15: ISO 55001 elements of an asset management system [ISO55001]

The next chapter will show the feasibility of implementing an asset management system (maintenance oriented) within the ETMU's context.

The proposed management system will try to be compliant with ISO 55001: 2014 requirements.

The main assumptions will be:

- The management system will only address assets and maintenance activities
- There are no outsourced activities

Chapter5:

Implementation study of Asset Management within the ETMU according to the requirements of ISO 55001:2014 standard

5.1. Introduction

ETMU is a unit acting in the transmission field at the operational management level. It manages an asset portfolio that is fixed by an internal organisational geographic subdivision.

Its main mission is monitoring and maintaining assets. As a result it mainly manages two phases of the asset life cycle: Maintenance and modification.

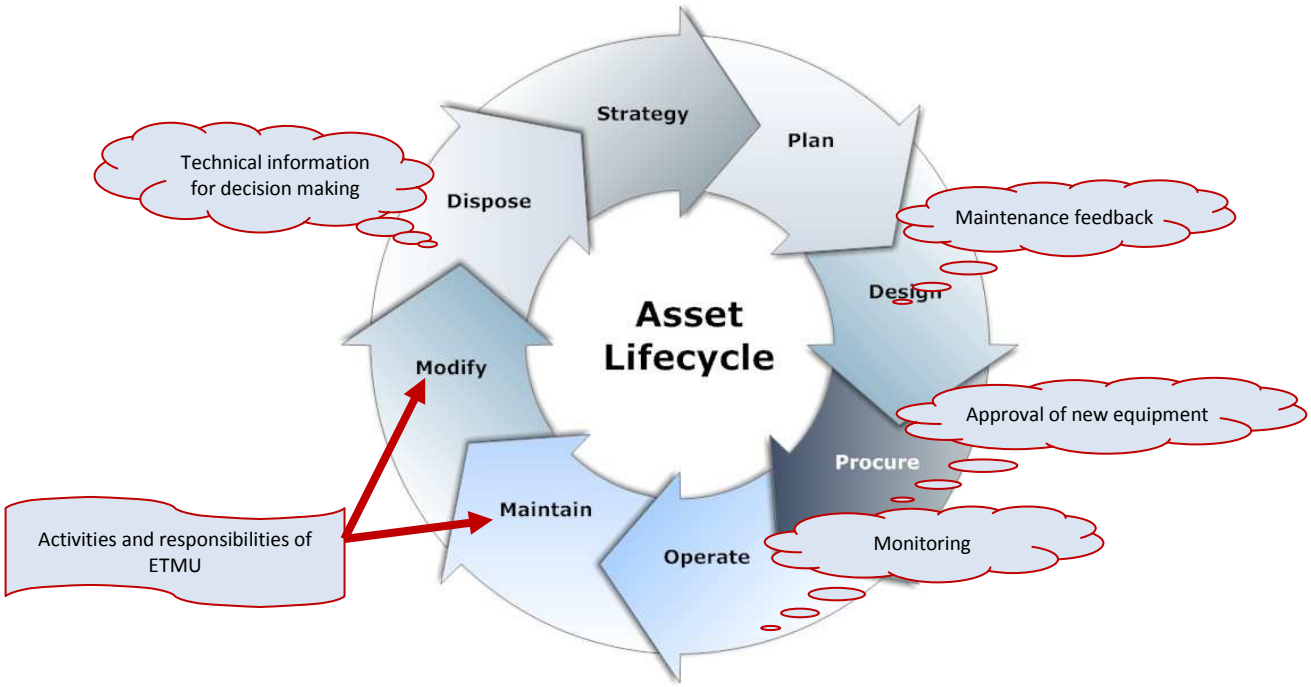


Figure 4.1: Asset lifecycle

As it is shown above, and despite that ETMU has some extra responsibilities which will not be covered by the proposed management system. Asset management will give an opportunity for ETMU to sustain those extra activities with reliable gathered information, accurate asset condition data, the introduction of risk management and the continuous seeking for improvement.

Thanks the asset management, the operational level, where ETMU acts, will be connected to the corporate strategic levels. It will comply with requirements of internal and external stakeholders (of ETMU and STEG).

This study will

- Offer a roadmap for the establishment of an asset management system focused on maintenance activity within ETMU
- Be the first step for implementation of the asset management system for a higher level of management, broader scope of assets, and that covers the totality of the asset lifecycle.

The management system will try to satisfy the72 “shall” requirements in ISO 55001. Many of the ‘shall’ are extensive obligations to design, develop, build and support business processes spanning the organization and its lifecycle, including applicable external interactions. [Sondalini; 2014]

The developing asset management plan will fit the PDCA framework exposed in the standard and divided into seven main elements:

1. Organisational context;
2. Leadership;
3. Planning;
4. Support;
5. Operation;
6. Performance evaluation;
7. Improvement.

[Sondalini; 2014] has presented an asset management system requirements framework that will be considered as a guideline for shaping and elaborating the asset management system within the ETMU.

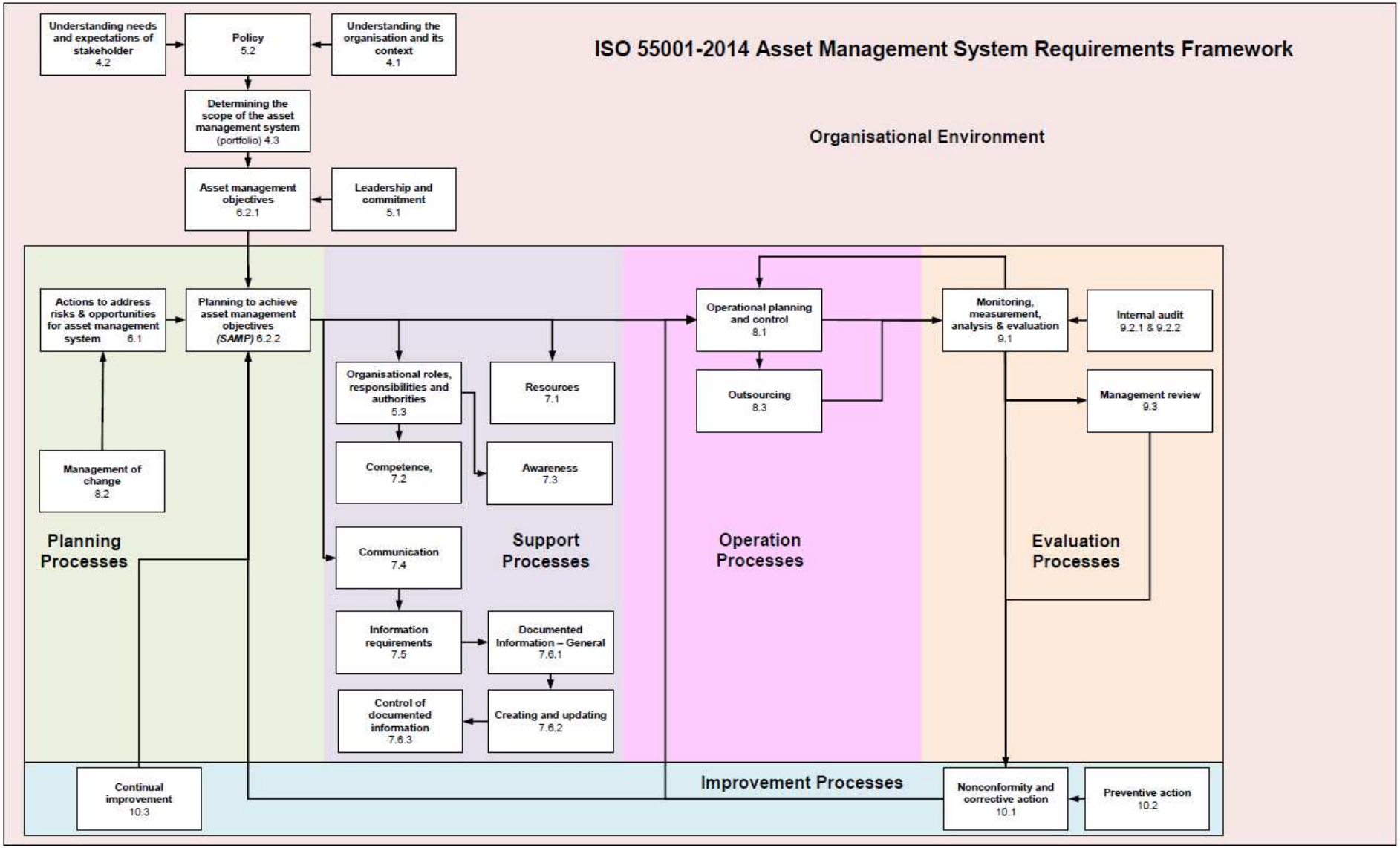


Figure 5.2: ISO 55001: 2014 Asset management system requirements framework

5.2. Asset management policy, strategy and objectives

According to ISO55001, the organization shall understand its context. That means understanding the internal and external environments, jurisdiction laws and regulations, the stakeholders within and without the organization, and the organization's purpose(s) and goals [Sondalini; 2014].

The asset management should take account of context constraints and Stakeholders requirements, and coalesce answers to those factors into its asset management policy, its asset management strategy and its asset management objectives.

To sustain the establishment of the asset management system, the top management should show its leadership and commitment.

The elaboration process, based on ISO55001 requirements is shown in the figures below

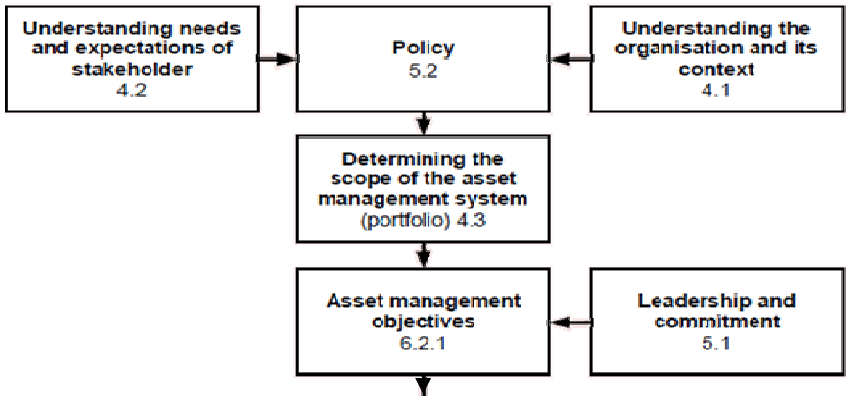


Figure 5.3: Implantation of asset management policy, strategy and objectives

The output of this process will be:

- The asset management policy statement
- The strategic asset management plan (SAMP)
- Asset management objectives
- The stakeholders register
- The asset management scope
- The assets register.
- The assets activity registers

5.2.1. Understanding the organization and its context

Clause 4.1 is concerned about understanding the internal and external environment. That means answering to the following questions [Sondalini; 2014]:

- How external issues may impact the asset management system with subsections on the legislative and regulatory environment, commercial environment, economic environment, social environment and natural environment?
- How internal issues may impact the asset management system and includes subsections on corporate direction, business frameworks and financial sustainability?
- How demand for services and assets may change as a result of external drivers?

Paragraph 3.3 of the current document, has executed a strategic study about STEG as whole entity but focusing on the electricity transmission SBU[22]

As a result we obtained a SWOT matrix that enumerates the opportunities and threats facing the organization, in addition to its weaknesses and strengths.
The matrix summarizes the parameters that could influence organization in delivering its objectives.

The analysis has shown the need for a trade off between technical performances and financial performance. In addition, the need for optimize the use of its resources and to improve its skills. Those objectives could be achieved by the use of the asset management system.

Thus, the previous chapters have shown the progression from the organizational objectives to the asset management objectives. It demonstrates the alignment of organisation and Asset management objectives as it required in **clause 4.1** of ISO 55001

5.2.2. Understanding the needs and expectation of stakeholders

The **clause 4.2** is concerned about stakeholders of the ETMU. The requirement asks to:

- Identify all internal and external stakeholders and their expectation
- Identify stakeholders' information and reporting requirements
- Develop asset management decision criteria

The stakeholders register presented in the annex chapter IV satisfies the requirement of the standard.

5.2.3. Policy

A definition of asset management policy could be defined as: A set of principles and mandated requirements derived from and consistent with, the organisational strategic plan, providing a framework for the development and implementation of the maintenance strategy and the setting of the asset management objectives

[22] Strategic Business Unit

The asset management policy document stems from the strategic study and the understanding of stakeholders requirements. It shall be compliant with the organization mission, strategy and show the organization commitment.

The asset management statement in chapter VI paragraph 2 of the annex comply with **clause 5.2** requirements

5.2.4. Determining the Scope of the Asset Management System

The **clause 4.3** sets the boundary on the assets in the asset management system and the coverage of your asset management system. Two document stems from these requirements:

- The scope of the asset management presented in the annex chapter III paragraph 9
- The **asset register**[23] presented in the annex chapter IV

In fact, the transmission assets are divided into two main portfolios

- Lines and cables
- Substation equipments: this group is also divided into
    - The Primary plant: composed of a set of switchgears and every switchgear is a set of high voltage devices such as Circuit breakers, Disconnectors, Transformers and Autotransformers, Reactors and capacitors, Measurement devices...
    - The Secondary plant: composed of Control's circuit, Protection relays', Communication equipments, Backup power supply...
    - Infrastructure assets: Building, fences, earth mats...

The diversity of transmission assets, its different functions and techniques, its geographic spread added to the fact that some assets have a shared maintenance responsibility between several departments. All those constraints lead to the use of CMMS for the edition of "**the assets register**[24]".

In addition, all activities integrated in the scope of the asset management system are related to those assets. Those activities are also integrated in the CMMS data base.

As a result, the uses of the ETMU's CMMS data base satisfy the requirement of the availability of documented information[25].

[23] Clause 4.3 requirement

[24] An assets register is a document that lists all assets owned by an organisation. It could contain some pertinent details about each asset such as technical information, location, value, depreciation...

[25] clause 4.3 requirement

5.2.5. Asset Management System

Clause 4.4 is concerned by the establishment of asset management system. Every process used in asset management will need to be defined and specified. It requires flow charting every process with all its interactions, and putting into place procedures of how to correctly do each phase and step of a process. This requirement was treated in the annex chapter VI paragraph 6 and chapter XI

The organization must develop a SAMP[26] including documentation of the role of asset management system in achieving the asset management objectives. Chapter VI in the annex tries to satisfy this requirement.

5.2.6. Asset management objectives

ISO 55000 defines 'objectives' as the results to be achieved. The asset management objectives are the specific results required from assets and assets activities. Since achieving the organisational objectives is the purpose of the asset management objectives there is natural alignment between the organization's objectives and its asset management objectives. [Sondalini; 2014]

The output from planning and setting the asset management objects will be a list of SMART (specific, measurable, achievable, realistic and time-bound) objectives.
The **clause 6.2.1** of the standard is satisfied by the Asset management objectives statement in the annex Chapter VI paragraph 5.

5.2.7. Leadership and commitment

Clause 5.1 requires top management to demonstrate leadership and commitment with respect to the asset management system. There are a number of criteria specified that need to be met to demonstrate this leadership and commitment, including; resourcing the asset management system, communicating the importance of asset management, cross-functional collaboration, continual improvement and risk management.[IMMM; 2014]

This requirement couldn't be satisfied at this level. This study aims first, to present the new standard for top management and to prove its necessity and its applicability at STEG.

[26] SAMP: Strategic Asset Management Strategy

5.3. Planning processes

How to achieve the organization's asset management goals (the achievement of which aids in delivering the organisation's objectives), address stakeholders' needs and requirements, and address the risks and opportunities that occur to the asset, the asset management, and the asset management system is the scale of planning that needs to be undertaken. [Sondalini; 2014]

Planning processes transform the SAMP into activities plans that target to deliver asset management objectives.

This process shall take account of risks and opportunities inherited from the assets management activities. Any change in assets or asset system could induce new risks or opportunities, which impact the asset management objectives delivery.

Planning should also take account of resources and competences availability, it should optimize the use of resources and prioritize activities and re evaluate risks.

The improvement actions should be integrated as a feedback of the ongoing processes

As a result, the output of the process is the Asset management plan (s)

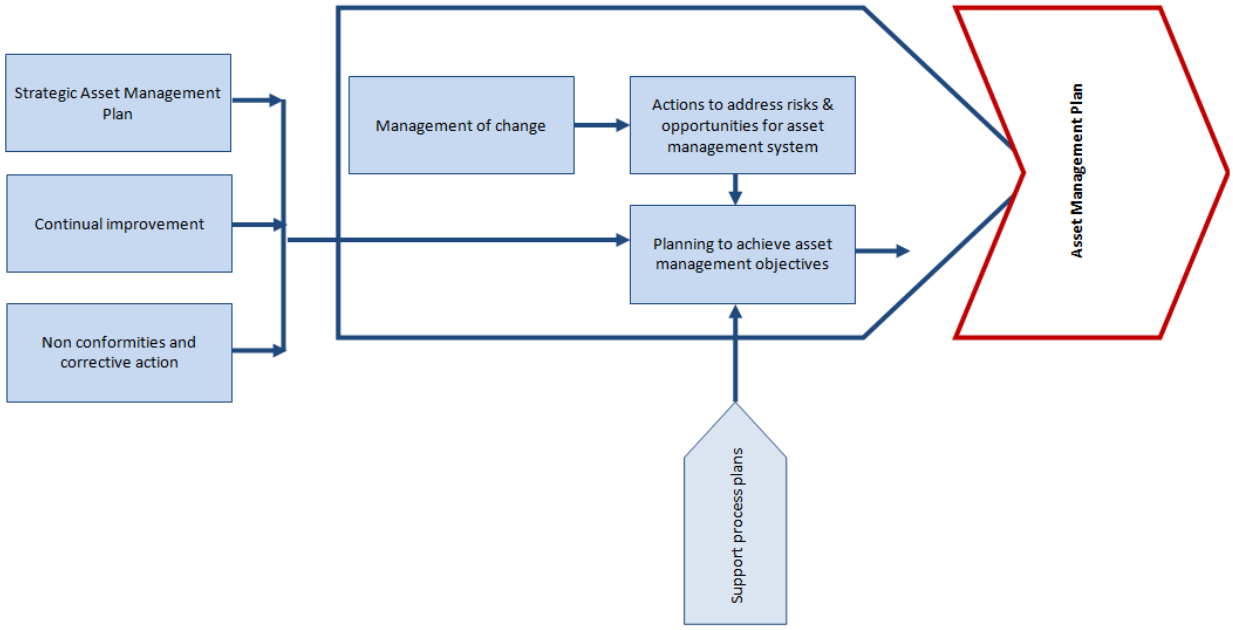


Figure 5.4: Update and re edit of asset management plan process

5.3.1. Actions to address risks and opportunities for the asset management system

Clause 6.1 deals with addressing the risks and opportunities that need to be considered when planning for the asset management system to achieve its intended objectives and outcomes, and how they might change with time. [IIMM; 2014]

The process of addressing risk could be divides into two main sub-sections:

- Identify and evaluate risks that could prevent achievement of asset management objectives
- Plan actions to address risks and monitor the effectiveness of these actions

The risk management at STEG is a quite new discipline. However, the “Risk Management Project”, an established internal project, has already analysed the generated risks from transmission maintenance activities.

Thus, the risk identification and evaluation methodologies and the risk treatment are already done. The risk register stemming from this work could be easily adapted and adopted within the ETMU. (See annex chapter VIII)

In addition, an evaluation of assets criticality is presented in the annex chapter VIII paragraph 5.The evaluation follows the same methodology used by the risk management project. However, the criticality of an asset is related and generally determined basing on the impact of the failure of the equipment on the system and the probability of fail occurrence.

The evaluation can be based on several parameters such as [E.Rijks & al, 2010]:

- Financial consequential
- Service/reliability consequential: The quantity of energy none transferred.
- Safety consequential
- Legal consequential
- Image/Reputation consequential
- Regulatory consequential
- Environment consequential

As an answer to the failures risks, the elaboration of the contingency plan is a must. According to [N Kolibas, 1998], the generic contingency plan document provides planned responses to possible asset failures, resulting from consequent or independent co-incident events, where such failures take the transmission system outside the boundaries of planned operational risks.
The events can be caused by a variety of causes:

- Environmental sources such as lightning, fires, earthquakes, cyclones, birds, trees;
- Human sources such as vandalism, accidents;
- Malfunctioning of other equipment, explosions of adjacent plant and failure of protection systems.

These plans ensure that every transmission asset in the network can be suitably replaced and power supply restored in the proper time. The asset identified in need of further consideration beyond the scope of the generic contingency plans will require a special contingency plan.

To summarize, the output of this process is

- The risk register
- The list of critical equipments
- The contingency plan

However, risk management is a dynamic process. During the operation process many risks could appear due to changes occurring on assets, assets system and asset management system. Any modification, decision, improvement should be risk assessed.

As consequence, the risk management should be an ongoing process. (Chapter XI of the annex)

5.3.2. Management of change

Clause 8.2 deals with prior assessment and management of any risks associated with any planned or unplanned change that could impact on achieving the asset management objectives [IIMM; 2014].

Changes are to be risk assessed with consideration of the impacts across the organization, including reviewing unintended consequences, adequate abatements are to be selected, and the implementation is to be thoroughly planned. Only after going through the whole change management process are the specified changes to be done [Sondalini; 2014].

Considering the close relationship between change management and risk management, they will be integrated in one process.

5.3.3. Planning to achieve asset management objectives

Clause 6.2.2 deals with establishing and maintaining asset management plan(s) that are aligned with the asset management policy and the strategic asset management plan (SAMP) to achieve the asset management objectives. The asset management planning must integrate with other organizational planning activities and consider requirements coming from outside the asset management system [IIMM; 2014].

According ISO 55002 the asset management plan could comprise:

- A justification of asset management activities (Annex chapter IX paragraph 1);
- The maintenance plans (Annex chapter IX paragraph 2). According to [N Kolibas, 1998], the Maintenance Plan is a complete list of maintenance work to be done on the assets currently operating in the system to ensure that they continue to fulfill their intended function in a cost-effective manner.
  The maintenance work in the Plan has three main maintenance categories:
  - Preventive maintenance work,
  - Corrective maintenance work,

    - Major works (after business case analysis for modification or refurbishment and operating funds approval)
- The capital investment plans (repair, renovation, replacement and improvement) (Annex chapter IX paragraph 3);
- Financial planning and resources (Annex chapter IX paragraph 3),

The asset management plan elaboration is an iterative process. It allows

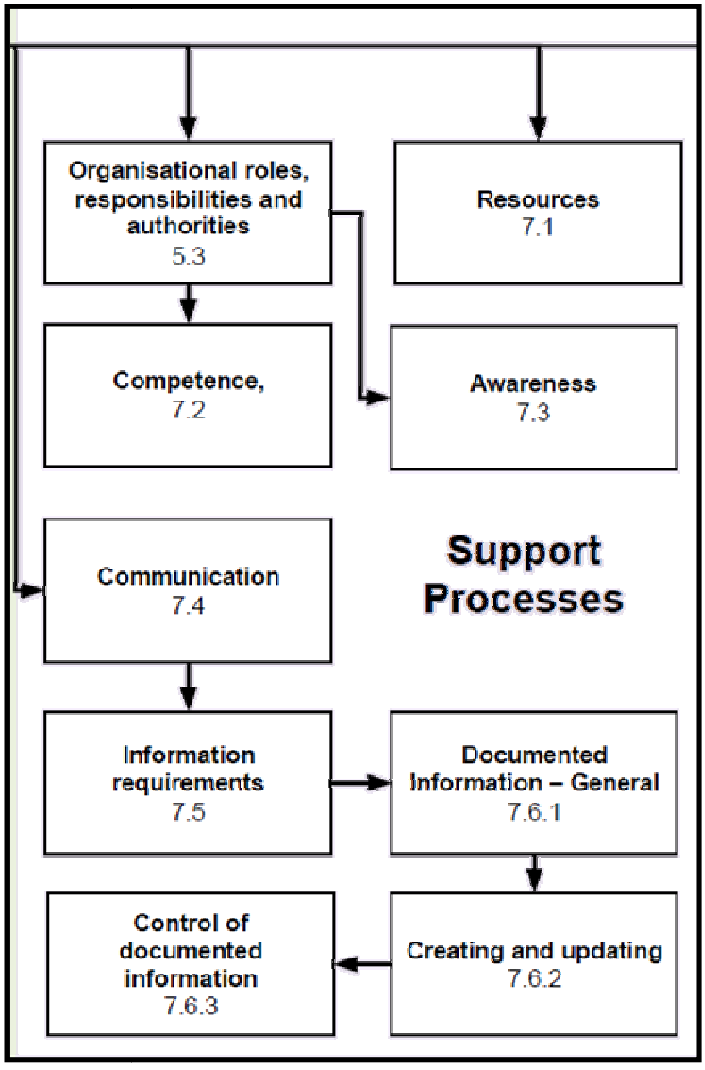
- The optimisation of the maintenance planning work and equipments' downtime,
- The sharing of information and the clearness of visibility for the different sub units,
- The optimisation of the use of materials spares RH, purchasing activities...,
- The optimal elaboration of the budget,

Obviously, the asset management plan is influenced by the risk evaluation process. In addition, while it is elaborated, the plan is impacted by resources and competence availability. However, support parameters are in an ongoing change so that the plan should be updated according to parameters' changes. To comply with clause 6.2.2 an asset management plan review process should be established (Annex chapter XI).

5.4. Support processes

For an asset management system to function correctly you need to provide the processes, infrastructure, financing, knowledge, skills, information management, service delivery and cultural environment that produces the intended asset performance for the organization. [Sondalini; 2014]. This involves

- The management of resources;
- The management of information and documentation;
- The promotion of awareness;
- The management of competence and knowledge;



5.4.1. Resources

Clause 7.1 deals with providing the necessary resources for the establishment, implementation, maintenance and continual improvement of the asset management system and for implementing the activities specified in the asset management plan(s) [IIMM; 2014].

This involve that ETMU should

- Provide resources to establish and maintain the asset management system
- Provide resources to implement the asset management plan
- Consider and evaluate internal and external resourcing

The ETMU has at its disposal a set of material and human resources. Some materials directly impact the maintenance activities such as:

- SF6 analyzer
- Gas recuperate
- Oil analyzer
- Current injectors for secondary plant tests
- Truck, cranes, Live-Line Insulator Washing truck
- Special tools for overhead line works
- Special safety devices and materials supported and controlled by the safety intendment.

Other materials are not directly involved in asset maintenance such as:

- Cars
- CMMS
- Some software used for HR and purchasing activities, they are maintained by the informatics department.
- Workshops for mechanical, overhead line and control system teams,
- .....

As same, ETMU has at its disposal a specialized workforce dispatched on specialized work team.

The asset management plan (particularly the maintenance plan) enumerates a list of task that should be done. Those tasks are organized according to the risk evaluation process. However, the resource management process will reorganize the maintenance plan according to resources availability. In addition, the resourcing Gap Analysis will identify gaps between the ETMU's capabilities and the requirements needed to achieve its asset management.

During this process, all financial support, safety, human, equipment, tools, capital expenditure, internal and external resources will be identified and addressed.(see Annex chapter XI paragraph 1). The establishment of the resource management process is an answer to **clause7.1** requirement of ISO55001.

5.4.2. Organisational roles, responsibilities and authorities

Clause 5.3 deals with the obligation for top management to ensure that the responsibilities and authorities for relevant roles are assigned and communicated within the organization. [IIMM; 2014]

The documented organisational chart (see annex chapter I paragraph 2) assign and communicate responsibilities and authorities while executing maintenance activities.

As a result, each team has its delimited task. However, the ETMU should establish a job description sheets as an accurate description for every role.

The **clause 5.3** requires also the assignment of asset management system responsibilities. (See annex chapter X paragraph 2)

The finality is that all responsibilities and authorities for each role are to be clearly specified so persons within and without the within the ETMU understand who is responsible for an activity [Sondalini; 2014].

However, the distribution of responsibilities and authorities through the ETMU implies:

- The dissemination of asset management awareness;
- The concern about competence and skills level of asset management actors;

5.4.3. Competence

Clause 7.2 covers the necessary competence (based on education, training or experience) of person(s) doing work that could affect the performance of assets, asset management or asset management system. It looks at acquiring the necessary competence, evaluating action taken, reviewing current and future needs and documenting evidence of this.[IIMM; 2014]

ISO 55001 wants to make clear that delivering the asset management objectives requires integration and cooperation of able and competent people within and without the organization who understand all what needs to be done and work together effectively to achieve them. [Sondalini; 2014].

This requirement needs three actions [IIMM; 2014]:

- Determine competency requirements
- Ensure competency and take actions if required
- Document evidence and periodically review

To achieve this task, the ETMU should establish a HR management process.

Through this process the ETMU will:

a) Determine the necessary competence for personnel performing asset management activities. The knowledge areas are
   - Academic level
   - Physical fitness
   - Knowledge about assets
   - Knowledge about asset maintenance activities

- Knowledge about safety standards
- Experience
- Team management
- so forth

The required competencies depends of the role and it will be convenient to declare those requirements in the Job description sheet

b) Identify the current competencies and giving proofs:
In fact, the recruitment process within STEG, guarantees a level of competencies. New recruits have a basic competency, and a pre-integration process. However the ongoing competencies building process is not controlled. The following up tool is available (every employee has its personal file where his professional career is tracked) and ETMU should enhance this task. The professional file will be the documented proof of competencies and at the end of the assessment phase the ETMU will define the competencies at its disposition.

c) With "Gap Analysis", ETMU will define its training and/or competencies needs. The needs will be expressed in the Asset management plan through the training plan.

d) Evaluate the effectiveness of the actions taken, by the execution of a yearly individual interview where every level of the hierarchy auditions his subordinates

e) Ensure that its personnel are aware of the relevance and importance of their activities and how they contribute to the achievement of the quality objectives, and

f) Maintain appropriate records of education, training, skills and experience

Looking for improvement, three actions could be taken:

- To recruit: In case of ETMU, the unit expresses simply his needs but cannot monitor, neither control the rest of recruitment process.
- To subcontract the competence, and this is the case of some high level of maintenance that needs a high level of expertise (generally, the manufacturer is solicited)
- To invest in training, this should increases the knowledge capital of the ETMU and creates new opportunities to the whole corporation.

In term of new recruits integration and internal training:

- A systematic integration plan should be established
- A list of information that new worker should receive and assimilates should be established and an assessment test should be done to document and evaluate new recruits progression
- A companionship process[27] could be established

[27] A companionship process: to choose a companion or a mentor who supervises and assist the new recruits during his integration process.

A list of documents and records has to be established to competencies such as:

- Competencies reference (list)
- Recruitments needs' : formulated in the annual budget document
- Training plan
- Individual Training request
- Assessment file of training efficiency
- Post description

As any other process, competencies management process is an ongoing process. Changes in ETMU's workforces and competencies is always happening and it induce many iterations in the formulation of the asset management plan and modifications and updating during its execution. (See Annex chapter XI)

5.4.4. Awareness

Clause 7.2 deals with ensuring awareness by all who can impact the asset management objectives. There are a number of criteria specified which address specific awareness of issues like the asset management policy, work activities including associated risks and how these benefit effectiveness, and performance and implications of not meeting the asset management system requirements.[IIMM; 2014]

To reach awareness within the ETMU, employees generally should be aware of the ETMU's asset management policy and particularly how every actor could impact the asset management objectives delivery and the induced consequences.

The fact of displaying the asset management policy and showing the top management commitment contributes to spread awareness among the incumbent actors. Meetings, debriefings, so forth are useful tools.

This study is a way to spread awareness among top management of the necessity of the implementation of asset management system.

5.4.5. Communication

Clause 7.4 deals with internal and external communications relevant to assets, asset management and the asset management system. It includes the what, when, who and how of communication. [IIMM; 2014]

There needs to be a strategy with plans and communication vehicles to get the right information to the right people, inside and outside the organization, at the right time. ISO 55000 guide recommends the use of a **Communication Plan.** [Sondalini; 2014]

What will be communicated? : Information about individual assets, your assets' management, and the asset management system.
In the ETMU, the main information is about the asset condition. According the asset condition a multi directional communication flows would be sparked.

In the ETMU's context, almost related to the asset information, the asset management information are also important considering that assets are also exploited and managed by others actors. So it's obvious to communicate the consistence of activities on those assets. The assets management system targets to satisfy stakeholders' requirements.
Communication of asset management policy, strategy and objectives are necessary. Moreover the communication should be in the two directions.

When communicate information? : The ETMU is situated at the operational level and permanently in connection with assets. On the other hand the grid manager doesn't have a physical connection with assets. This induces that the asset condition dictates the communication frequency. A permanent communication flow is established between the ETMU and the internal and external stakeholders and it is activated according to the emergency level.
In addition, ETMU should also communicate while it is establishing or updating its asset management policy, strategy or objectives.

Who will communicate? : The communication flows are already established within ETMU. Daily communication about asset condition and grid operation should be done through the "Office Guard- "Bureau de garde"; Weekly communication about maintenance activity should be done through the coordination office "Bureau de methods" and all other communication through the Unite manager.
The stakeholders register gives an exhaustive list of communication partners.

How communicate? : The official means of communication at STEG are written communications. The communication should be by the way of faxes, Memos and reports. However for the daily communication the use of oral communication transcribed into written document is admitted. Emails are also used for some communication flows. The CMMS is also a communication means. Documented asset management policy, strategy and objectives are also means of communication inside and outside ETMU.

This previous phase was about determining communication requirements. As consequence a Communication Plan could be developed. This plan could comprise according to ISO 55002, clause7.4.3

- The benefits generated by the implementation of an activity, project, program, or a change or an increase in assets, and how these improvements are expected to collectively or individually impact the parties stakeholders and the organization;
- A schedule of improvement, including key milestones, people involved, and for how long;
- Any specific communications resources, including statements of expectations of the asset management system;
- "who", "why", "when" and "what" of the information provided, including how the organization is to achieve its objectives, the management of assets contributed;
- Where appropriate, what external and internal knowledge is necessary for stakeholders to make informed decisions or contributions, or for feedback?

- The most appropriate person representative to convey specific information;
- The format to use for communications;
- The processes of feedback and reporting.

Finally, to satisfy the requirement of **clause 7.1** of ISO 55001, ETMU should edit its Communication Plan. This plan is based on existed communication practices. But, the difference will be in the content. The information shall be about assets, asset management and particularly the asset management system.

5.4.6. Information requirements

Clause 7.5 deals with the information requirements across all elements of asset management. There are a number of criteria specified which address risks, asset management roles, responsibilities, processes, activities and information exchange and impacts on decision making.[IIMM; 2014]

All information requirements related to the relevant assets, asset management, the asset management system and the achievement of the organizational objectives are to be identified and addressed [Sondalini; 2014]

Within the ETMU, information is managed by the CMMS. Actually, while establishing the software, the ETMUs have fixed their needs of information. The process was mainly asset centric. The data base of the CMMS keeps all technical information about assets and related maintenance activities. The CMMS is supposed having multiple interfaces according to management level and users requirements.

However many actors do not dispose of access. Even more, the gathered data could not satisfy their needs.

The ISO 55001 wants that information should be considered regarding risks, roles, processes, stakeholders, and the content and worth of the information for decision making.

The communication management process determined communications channels inside and outside the ETMUs. Furthermore, it has to shape the information requirements.

Practically, it is a tough mission to fix information requirement at the planning stage. The determination of information requirements including attributes and quality needed to support asset management system should be an iterative and ongoing activity.

Clause 7.5 requires the Implementation of a data maintaining processes and the establishment of appropriate data repositories.

The establishment of the CMMS and all sub consequent activities satisfy these requirements. However, there is a lack of procedures that deals with: how and when collect asset data.

5.4.7. Documented information

Documented information is defined in ISO 55000 as, ‘information required to be controlled and maintained by an organization and the medium on which it is contained.

Clause 7.6.1 deals with documented information as part of the asset management system which includes that required by the International Standard, that applicable for legal and regulatory requirements and that deemed necessary from **clause 7.5**.[IIMM; 2014]

Through this chapter the required documents are:

- The Strategic Asset Management Plan
- The Asset Management Plan

For legal and regulatory requirement there is a plenty of document, particularly for safety reasons that are required such as

- Empowerment document
- Work permit
- So forth

For asset management system, the documentation is created during the establishment of the system such as:

- Stakeholders register
- Asset register
- Risk register
- Communication plan
- So forth

For maintenance management, within the ETMU, There are many required documents that should be present or created.

[Guillaume; 2009] enumerates:

- The technical documentation related to equipments;
- The maintenance plan;
- The historical log of maintenance.

Also in relation to that, [N Kolibas, 1998] quotes that the required documents for the implementation of a maintenance management system for transmission assets are:

- The maintenance policy manual (integrated in the strategic asset management plan),
- The Maintenance Services Manual[28], (a missing but necessary document for any ETMU)

[28] According to [N Kolibas, 1998], the Maintenance Services Manual defines maintenance servicing work specifications, which are detailed, hands-on, step-by-step servicing instructions used by crews performing maintenance. These instructions originate from the manufacturers maintenance servicing manuals and instructions, and are supplemented by extensive in-house experience in maintenance and exchange of information with other utilities and service providers through the industry bodies and forums

- The Generic Contingency Plans,

[N Kolibas, 1998] also emphasizes on the importance of reporting activity. He enumerate such reports that could be useful for ETMU such

- Asset Corrective Maintenance Work Report;
- Asset Failures Report;
- Asset Failures Summary Report;
- Asset Population/Attrition/Performance Summary Report.

Clause 7.6.2 deals with creating and updating documented information. The need for a structured and consistent way to develop, approve and maintain documents.

Clause 7.6.3 deals with the control of documented information required by the asset management system and by the International Standard, to ensure it is adequately protected and available for use. There are a number of criteria specified which address amongst other things, access, retrieval, storage and preservation. Relevant external documented information shall also be appropriately identified and controlled.

To satisfy the two requirements, ETMU could use the processes and procedure used in other units certified ISO 9001:2008.

5.5. Operation processes

5.5.1. Operational planning and control

Clause 8.1 deals with the processes needed to implement the planning actions in addition to the corrective and preventive actions determined in **clause 10.1** and **10.2**.[IIMM;2014]

Actions selected during your asset, asset management, and the asset management system planning should be executed. All processes, from their beginning to the end, have to be put into use and ought to operate as intended. The methodology to use for this clause is Process Mapping. [Sondalini; 2014]

While mapping the asset management processes, The ETMU could identify risks in processes, use appropriate risk controls, specify records of evidence from the process, and the performance measurements. The use of the 5M tool (**Ishikawa diagrams**) will allow the modelling, monitoring, and auditing of the processes.

The Figure 5.5 shows the process mapping of the established management system. The suggested processes are:

- Processes for the management of an organization[29]
    - SAMP review
    - Update and re edit of asset management plan
- Processes for managing resources.[30]
    - Competence management
    - Ressources management
    - Information management
    - Communication management
- Realization processes[31].
    - Maintenance process
- Measurement, analysis and improvement processes[32]
    - Performances evaluation
    - Risk analysis
    - Improvements

The suggested solution is just a draft of the process mapping and asset management processes Chapter XI). While establishing the asset management system, many changes could happen.

[29] Processes for the management of an organization: These include processes relating to strategic planning, establishing policies, setting objectives, communication, ensuring availability of resources for the other organization's quality objectives and desired outcomes and for management reviews.

[30] **Processes for managing resources:** These include all the processes that are necessary to provide the resources needed for the organization's quality objectives and desired outcomes

[31] **Realization processes:** These include all processes that provide the desired outcomes of the organization

[32] **Measurement, analysis and improvement processes:** These include the processes needed to measure and gather data for performance analysis and improvement of effectiveness and efficiency. They include measuring, monitoring, auditing, performance analysis and improvement processes (e.g. for corrective and preventive actions). Measurement processes are often documented as an integral part of the management, resource and realization processes; whereas analysis and improvement processes are treated frequently as autonomous processes that interact with other processes, receive inputs from measurement results, and send outputs for the improvement of those processes

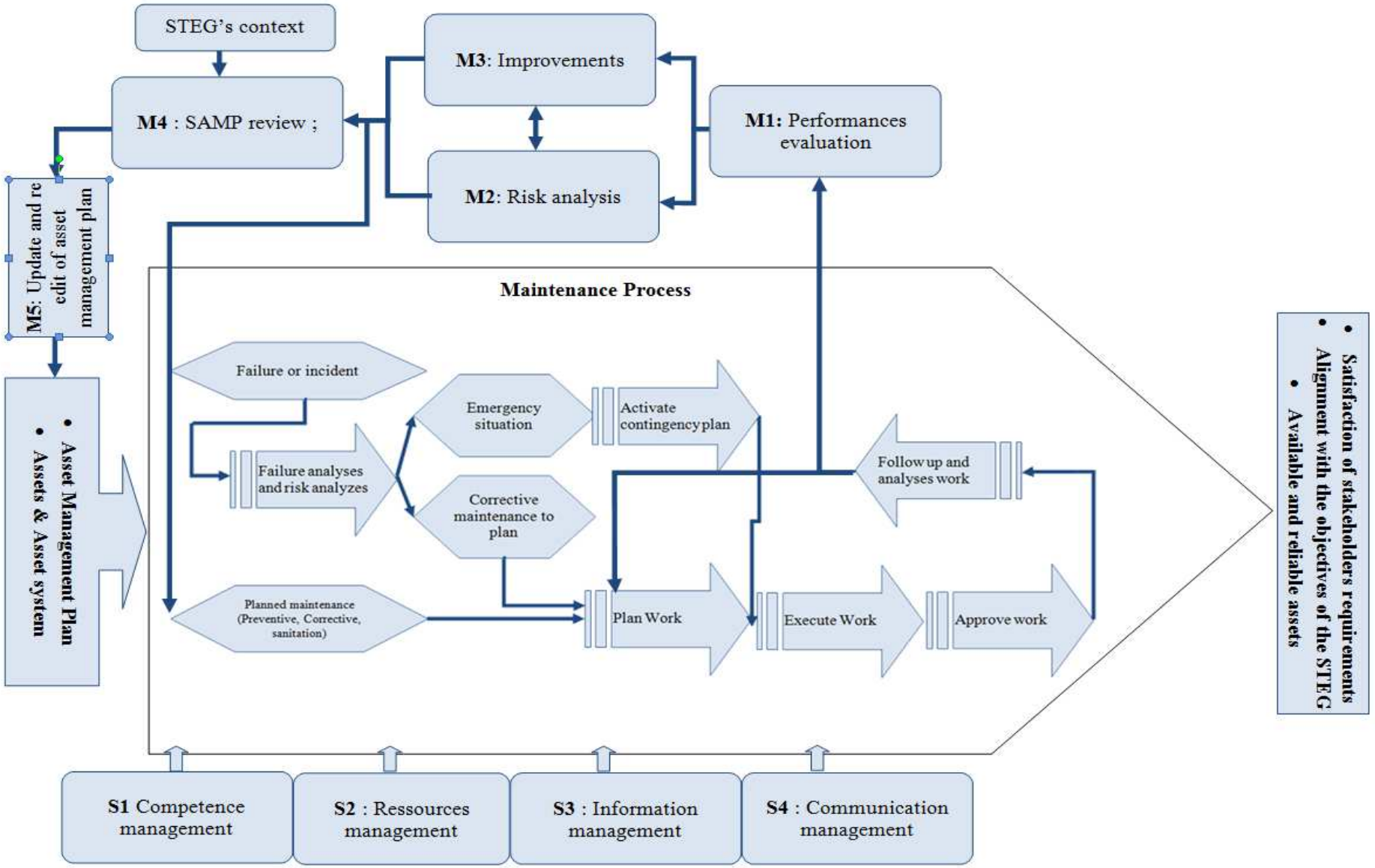


Figure 5.5: Process mapping of the asset management system

5.6. Evaluation processes

Monitoring and evaluating the performance of assets, asset management and the asset management system against their respective objectives is necessary to ensure the desired outcomes are being achieved effectively. This provided confirmation of satisfactory or unsatisfactory performance, along with highlighting opportunities for improvement. [Sondalini; 2014]

5.6.1. Monitoring, Measurement, Analysis and Evaluation

Clause 9.1 deals with what and when to monitor, and measure and report on performance (including financial and non-financial performance) and the effectiveness of the asset management system. [IIMM; 2014]

The information collected by monitoring, measurement, analysis and evaluation is for the purpose of improving the effectiveness of the processes used in the organisation and ultimately to improve the organization's performance at meeting its owner's and stakeholder needs. [Sondalini; 2014]
To monitor it is necessary to adopt measures such performance indicators.

5.6.1.1. Asset performance monitoring Indicators

The main activity of ETMU is to monitor and maintain assets. As consequence it is important to pick the performance of assets and asset management.

According to [Guillaume; 2009], key performance indicators should:

- Despite the complexity of the management system, kept as simple as possible;
- Be always related back to the organization objectives;
- Be easily associated to and influenced by an already defined activities;
- Be easily measurable or constituted by a set of easily measurable values;
- Be comparable over time and capable to show a tendency;

[Simons; 2010] adds some other characteristics such as:

- Be quantifiable, Both Objective and Subjective data must always be quantified
- be reviewed or subject to continuous improvement
- be communicated in an appropriate manner to all sections of the workforce

Considering the main activity of ETMU that is maintenance. The performance indicators should be adapted to this activity.

The commonly used maintenance performance indicators According to [Weber & Thomas; 2005], fall into two categories:

- Leading indicators: Keys performance closely related to the maintenance process/efforts. They are process assurance measures and they try to answer to the

question: "how do I know that this maintenance process element is being performed well?"

- Lagging indicators: Keys performance related to result measures, they monitor the outputs that have been achieved

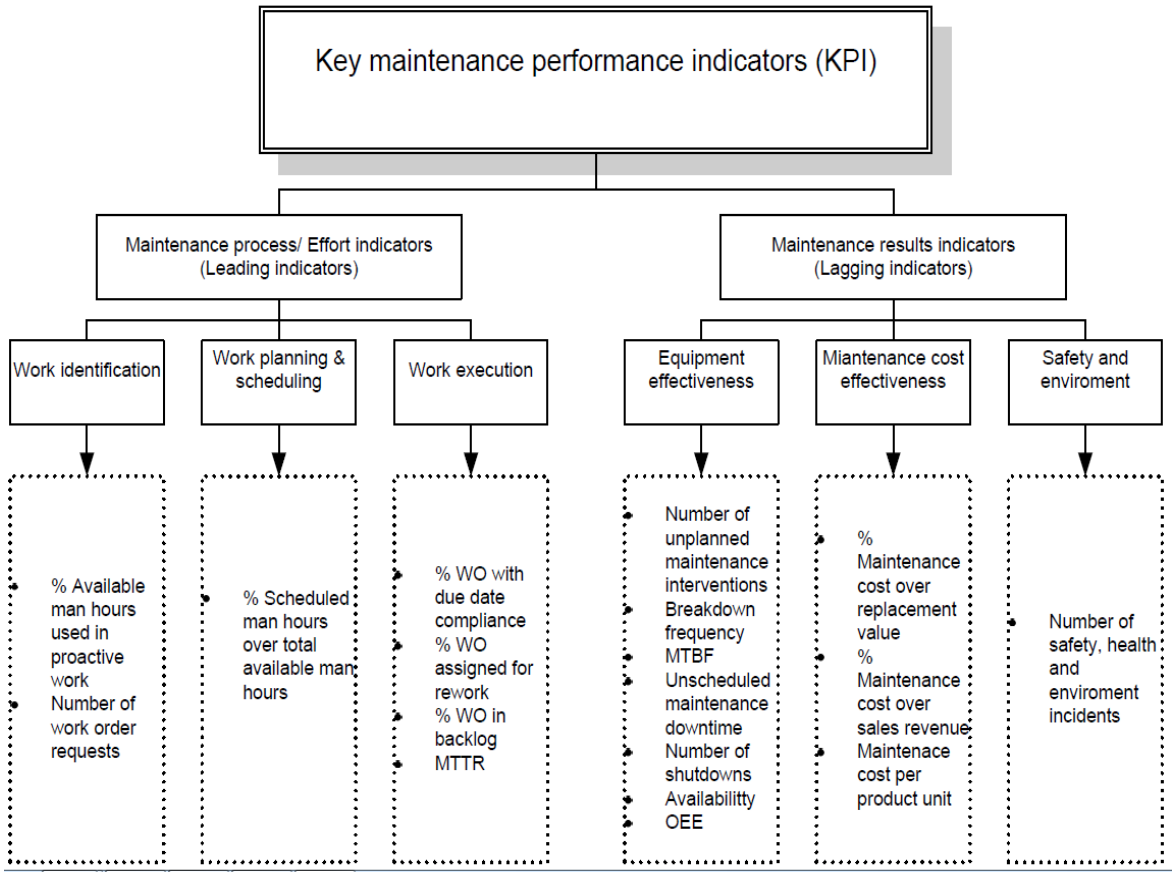


Figure 5.6: Key maintenance performance indicators in the literature [Kumar & al 2013]

EN 15341: 2007 stipulates that KMPI could be structured into three groups:

- Economics
- Technical
- Organisational

The same standard gives three levels enterprise:

- The company level
- System level
- Equipment level

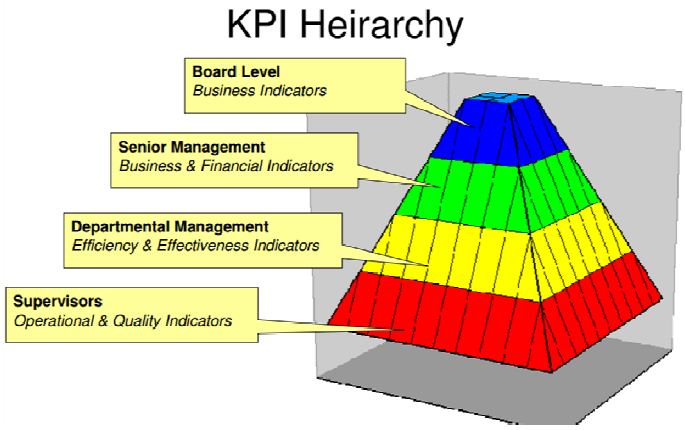


Figure 5.7: KPI hierarchy according to [Simons; 2010]

KMPI should be gathered in scorecards. Even more, the scorecards should be customized according to different maintenance requirements, and according to the management levels.

While dealing with transmission business, [Bodrogie & al; 2004] stipulates that TSOs, asset managers and service provider, such the ETMU, are looking for tools to assist them with the assessment of their performance and to permit them to keep as near to their regulatory and customer requirements. The overall aim is to offer the lowest possible cost grid with acceptable technical performance.

According to the same CIGRE's study, the maintenance KPI proposed includes Asset availability, Asset reliability, Outage maintenance, Maintenance budget achieved , Safety, Statutory compliance, Industry rule compliance, Service Quality indicators.

[Bodrogie & al; 2004] proposed the below KPIs in the case of the transmission business

- Availability indicators:
  - Energy not supplied (ENS)[33]
  - Average Interruption Time (AIT)[34]
- Reliability Indicators
  - System Average Interruption Frequency Index (SAIFI).35
  - Customer Average Interruption Frequency Index (CAIFI)[36].

[33] ENS: Summation of energy not supplied (interrupted power X duration) due to interruption excluding network losses (MWh/yr)

[34] AIT : measures the total number of minutes that power supply is interrupted during the year. (AIT = 8760*60*ENS/AD in min/year, where AD = annual demand (MWh/yr).

[35] SAIFI:This indicator, recommended by the IEEE, measures the average number of interruptions experienced by each customer. All planned and unplanned interruptions are used in calculating the index.

[36]CAIFI: This indicator, also recommended by the IEEE, measures the yearly average number of interruptions per affected customer. An affected customer is one who experiences at least one interruption during the year. CAIFI is used far less than SAIFI.

- Mean time between failures (MTBF)
- Mean time to repair (MTTR)
- Outages/100 circuit km
- Number of successful restoration operations
- Number of malfunctions of protection
- Number of failures/yr classified by cause.
- Risk Situation Index (RSI)[37]

- Service Quality Indicators
  - System Average Interruption Duration Index (SAIDI)[38].
  - Customer Average Interruption Duration Index (CAIDI)[39]
  - Customer Satisfaction Index (CSI), determined through inquiries;
  - Average Incident Duration (AID);
  - System Average Restoration Index (SARI).

According to [Bodrogie & al; 2004], maintenance cost[40]is used, as basic data to make comparisons, for instance, per voltage level, per planning unit, per maintenance location etc. Also, it appears more common to use the trend of maintenance costs to follow performance rather than as a ratio to total expenditure.

The recommended KPI for maintenance cost are:

Overhead Lines:

- Cost of maintenance of OHL/route length (km)

[37] RSI : is an index based on the calculated consequences of all possible 'n-1' situations e.g. overloaded line or transformer, voltage out of limits or high level of Mvar flow, probability of each 'n-1' situation. This index of risk increases with planned outages of grid elements. Because this indicator gives a continuous evaluation of system risk, it is considered valuable for system operation.

[38] SAIDI : This indicator, recommended by the IEEE, expresses the duration of outages customers experience during the year on average. All planned and unplanned interruptions are used to calculate the index. It is defined as the total hours of power interruptions normalized per customer served.

[39] CAIDI: This indicator, also recommended by the IEEE, measures the yearly average duration of interruptions normalized per affected customer. An affected customer is one who experiences at least one interruption during the year.

[40] A common definition of what main maintenance cost covers should include (and be limited to) the following items: basic enabling measures; recurring maintenance; corrective maintenance; operational replacement costs; environmental issues and obligations; and refurbishment. Capital replacement costs, financial and operational impact costs (like imposed energy production and penalties) should not be included.

Substations:

These costs should include all costs within the substation fence (i.e. HV, auxiliary, site, protection), subdivided as follows:

- Primary Equipment:
  Cost of maintenance of substation HV equipment/ (No. of CBs + p *No. of transformers), where it is suggested that p = 2.
- Protection:
  Cost of maintenance of protection equipment/ (No. of CB + No. of transformers).

In small organization, such KOSTT the TSO in Kosovo, they adopt "Internal Technical Performance". Those indicators monitor the operational level such as: [KOSTT; 2007]

- Line/ Cable Failure rate per 100 circuit km
- Average repair time of Line/Cable failures
- Average Outage time due to Line/Cable maintenance
- Transformer Failure rate per 100 Transformers
- Average repair time of Transformer failures
- Average Outage time due to Transformer maintenance
- Switchgear Failure rate per 100 bays
- Average repair time of Switchgear failures
- Average Outage time due to Switchgear maintenance
- Control/Protection Failure rate per 100 bays
- Average repair time of Control/Protection failures
- Average Outage time due to Control/Protection maintenance

Those indicators are more suitable to the ETMU context. Actually the indicators mentioned in the CIGRE study of [Bodrogie & al; 2004] give a good idea about the key performance for measuring the service level.
However, for the operational level, the ETMU needs more customized indicators like those used by KOSTT.

Currently, KPI used within ETMU are addressed to top management and aim to assess the service level. The indicators assessing the individual performance of assets and asset management are missing.

The ETMU also use Coswin 8 as CMMS, it proposes some leading indicators that could help for monitoring the ongoing performance of maintenance activities and the percentage of achieving the maintenance plan.

Figure 5.8: The ETMU's scoreboard

Those indicators could be considered as leading indicators. However, they don't really give a sufficient view about the charring out of the maintenance process.

Safety indicators have to be also used. STEG uses some genetic safety indicators that could be simplified to two or three simple and clear indicators such:

- Number of mortal Accident
- Number of non mortal accident
- Number of accident with and electrical root
- Number of unannounced safety visit
- Number of non conformities to safety prescription
- Safety training indicators
- So forth

In the same way there are some environmental indicators that may be monitored such as the SF6 leakages rate...

Risk indicators should be also set up. The risk register identifies the major potential risks that should be monitored and accordingly to establish measurement indicators for gauging the remaining risk level.

Recently, a security activity was created and performance indicators could be established.

As a first step, the actual asset management system will use the already established indicators. As a second step, a review of indicators according to different stakeholders' requirements and process needs.

5.6.1.2. Assets performances monitoring means

The main way to monitor and measures is the CMMS. The maintenance process within ETMU could be modelled as below

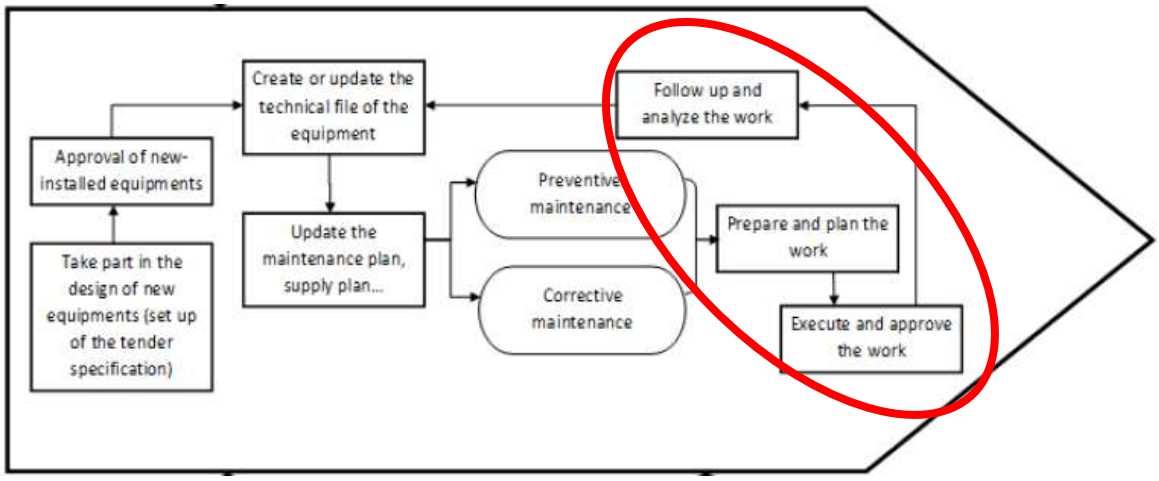


Figure 5.9: Maintenance process within ETMU

The red underlined sub processes are:

- Work planning
- Work execution
- Work follow up

Those sub processes are totally monitored with the CMMS software. And the data base is fully enough for monitoring asset activities.

However, for asset condition and performance indicators, the reports of other units are the main measurement mean. In the communication plan the ETMU should express its information requirement from other units.

5.6.1.3. Asset performance monitoring frequency

Within the ETMU, there are different Asset performance monitoring and so that different monitoring frequency.

The CMMS allows an almost constant monitoring. At any moment the ETMU could measure the progress of achieving the maintenance plan.

For measuring the asset performances, generally the ETMU use the reports of grid operators or other service providers. The frequency will be monthly or even yearly.

5.6.1.4. Asset performance analysis and reporting

[Guillaume; 2009] quotes that “analysis of data “is actually an analysis of the feedback of the maintenance experience the finality is to:

- Give an overall assessment of the management system

- Give an overall assessment of equipment performance
- Facilitate analysis of problem causes
- Assist in determining corrective and preventive actions
- Facilitate continuous improvement

Data analysis is a continual activity. Of course it is an input for management review (reactive monitoring) but it's also performed periodically and used as proactive monitoring tool. It's recorded in the different reports produced by the unit and it's closely related to improvement processes.

[N Kolibas, 1998] quotes that continuous monitoring; review and analysis of assets performance reports expose assets with deteriorating maintenance and system performance.

He suggested some reports model that could be used in the ETMU's context:

Asset Corrective Maintenance Work Report: Review of this report is used to decide if asset maintenance regime or servicing instruction needs to be investigated to obtain more information about its performance or condition;

Asset Failures Report: The review of report information will enable to determine if a further analysis of asset failures for asset types represented in these failures is warranted;

Asset Failures Summary Report: This report is used to highlight on a regular basis asset types that have fared prominently throughout their total years in service with regard to their failures when analysing the failures number, type and percentage to their total population;

Asset Population/Attrition/Performance Summary Report: This report is used to highlight asset types that have fared prominently throughout their total service years with regard to their terminal failures (i.e. plant had to be removed after the failure and discarded).

Those reports will be the outputs of the performance evaluation process.

5.6.2. Internal audit

Clause 9.2 deals with conducting internal audits to test conformance, implementation and maintenance of the asset management system.[IIMM;2014]

The organization shall conduct internal audits at planned intervals to determine whether the maintenance management system is:

- Conforms to the planned arrangements,
- Is effectively implemented and maintained.

The internal audit is supposed aiding ETMU to reach its objectives. It's a necessary and effective tool that helps to verify the good establishment of the asset management system. It validates system implantation compliance and that it will allow objectives achievements.

The progress of the audit is generally spread over three phases.

Preparation phase ➔ Realization phase ➔ Exploitation phase

The ETMU shall after the implementation of the system:

Establish an audit plan that delimits criteria and scope for each audit; selects auditors and audits to ensure the objectivity and impartiality of the audit process (the assistance of the audit department at STEG could be very useful); describes the reporting process of audit results to the concerned management level.

Obviously the audit process should detain documented information as evidence of the implementation of the program Audit and audit results.

The internal audit process is already used in other units certified ISO9001. As a first step ETMU could copy this audit process and to graft it into its context..

5.6.3. Management review

Clause 9.3 deals with top management reviewing the organization's asset management system to ensure its continuing effectiveness.[IIMM; 2014]

According to PAS55 (paragraph 4.7), Top management shall review at intervals that it determines appropriate the organization's asset management system to ensure its continuing suitability, adequacy and effectiveness.

According to [Fry; Crawford Linda; 2008], a management review is a formal meeting of key members of senior management. The purpose is to review the status and effectiveness of the management system. This meeting provides a venue for management to evaluate and analyze practices for the purpose of improvement. During this meeting, a comprehensive look-back at the organization's management system takes place. This includes a review of documented policies and a review of records.
Following the meeting, a list of action plans for improvement should be produced.

Reviews shall include assessing the need for changes to the asset management system, including asset management policy, asset management strategy and asset management objectives.

Review input	Review output
• Results of internal audits and evaluation of compliance with applicable legal requirements and with other requirements to which the organization subscribes; • The results of communication, participation and consultation with employees and other stakeholders; • Relevant communication(s) from external stakeholders, including complaints; • Records or reports on the asset management performance of the organization; • The extent to which objectives have been met; • Performance in addressing incident investigations, corrective action and preventive actions; • Follow-up actions from previous management review • Changing circumstances, including development in legal and other requirements related to asset management and changes in technology.	Decisions and actions for possible changes to: • Asset management policy, strategy and objectives; • Asset management performance requirements • Resources; • Other elements of the "asset" management system

Table 4.1: Inputs and outputs of management review according to PAS55:2008

Records from management reviews shall be maintained

Records of management reviews shall be retained and information relevant to specific employees, contracted service providers or other stakeholders made available for communication purposes.

Same case as Internal audit; **clause 9.3** could be satisfied by importing practices from other units that are certified ISO 9001 within STEG.

The adoption of practices, processes and procedure will be the first phase. Once the system is running changes, rectifications are always possible. In fact they can be considered as improvements.

5.7. Improvement Processes

It is expected that the design and use of the asset management system is improved. When there are problems they become opportunities to learn what more can be done to enhance the system. The best organisations are proactive at identifying potential risks and eliminating them and/or putting in place contingencies to mitigate opportunities to occur or that minimize the effects. [Sondalini; 2014]

After performing the audit process, monitoring and measuring performances of management system and the equipments condition; analysing data, we reached the improvement's stage

Independently of the activity sector, any management system has as end target to continually improve the organization's policies, procedures and processes.

And why not to move from improvement to the innovation. Actually, the effectiveness of the management system is reached when we carry out improvement action, it increases while applying the continual improvement process.

5.7.1. Non conformity and corrective action

Clause 10.1 deals with the organization reacting to any nonconformity or incident and taking action to control and correct it. [IIMM; 2014]

The organization shall establish, implement and maintain process (es) and/ or procedure (s) for handling and investigation of failures, incidents and non conformities[41] associated to assets, assets system and the asset management system.[PAS 2008]

These process (es) and/or procedure (s) shall define responsibility and authority for:

- Taking action to mitigate consequences arising from a failure, incident or nonconformity;
- Investigating failures, incidents and nonconformities to determine their root causes(s);
- Taking corrective actions[42] and evaluating its effectiveness
- Evaluating the need for preventive action(s) to avoid failures, incident and nonconformities occurring;
- Introduce necessary change in the asset management system via the change process
- Communicating, as appropriate to relevant stakeholders, the result of investigation and identified corrective action(s) and/or preventive action(s).

As well as any other process, documented information should be conserved. It shall comprise description about non conformity or incident, undertaken action and the result of

[41] Nonconformity is a non fulfilment of a requirement. In maintenance management we distinguish functional requirement and process requirement.

[42] Corrective actions are actions taken to address the root cause(s) of identified non-conformances, or incidents, in order to prevent, or reduce the likelihood of recurrence.

corrective action. A corrective action form could be established. This form is already used in ISO9001 certified units.

Same, the non-conformance Management process already exists in quality management; ETMU could also import and adapt this process to its Asset management system.

5.7.2. Preventive action

Clause 10.2 deals with the processes to proactively identify possible preventive action

'Preventive actions, which may include predictive actions, are those taken to address the root cause(s) of potential failures or incidents, as a proactive measure, before such incidents occur. The organization should establish, implement and maintain process (es) for initiating preventive or predictive action(s).' [ISO55002; 2014]

Closely related to corrective action, PAS 55:2008 emphasizes on the implementation and maintaining of process (es) and/or procedure(s) for instigating:

- Corrective actions (s) for eliminating the causes of observed poor performance and nonconformities identified from investigations, evaluations of compliance and audits to avoid their recurrence;
- Preventive action (s) for eliminating the potential causes of nonconformities or poor performance.

Furthermore, PAS55:2008 draws attention to the risk(s) encountered, Actually any corrective or preventive actions taken and their timings shall be commensurate with the risk encountered.

The process of implementation of improvement action comprises

- The measurement
- The identification of the (potential) problem
- Analysis
- Selection of the action
- Risk assessment
- Follow up (monitoring)
- Recording

To conclude; complying with **clause 10.2** and **10.1** induce the establishment of Conformity management process, or simply called improvement process that takes action for improving the asset management system. The ETMU could adapt the improvement process used in the quality management system. However, ETMU shall introduce in this process the risk awareness.

5.7.3. Continual improvement

Clause 10.3 deals with continually improving the organization's asset management and asset management system.

Continual improvement is not dependent of corrective or preventive actions and doesn't aim to change corporate organization or review its objectives. It's simply a process that seeks for new technologies, tools, methods that can aid organization to deliver its objectives.

It is an imperative that asset management system and its operation be continually improved through identifying opportunities to make it simpler, reduce its cost, do things faster, and delivers top quality results so as to become more effective and efficient. By actively making the organization's assets, asset management, and asset management system perform better all stakeholders benefit.

To comply with **clause 10.3**, ISO 55002 provides a clear methodology that delivers continual improvement through its use in the organization. The suggested approach includes the following steps:

- Identification of needs and potential for improvement;
- Evaluation of options;
- Estimation and determination of financial and non-financial consequences;
- Aspects of risk assessment and management changes;
- Links with decision criteria;
- selection and implementation;
- Monitoring and review of the results.

5.8. Implementation plan for an asset management system

The desired output of this study is an implementation plan for an asset management system within the ETMU according to ISO 55001:2014 requirements.

The ISO 55001 approach is mainly based on the Plan-do-check-Act cycle to drive continuous improvement. The asset management system ought to address six aspects of the organization:

- The internal and external environment,
- Planning processes,
- Support processes,
- Operational processes,
- Performance evaluation processes,
- Ongoing improvement processes.

Those aspects are covered by the following main clauses of the ISO55001 standard:

- 4: Context of the organisation
- 5: Leadership
- 6: Planning
- 7: Support
- 8: Operation
- 9: Performance evaluation
- 10: Improvement

As a result, a modelling of the Asset management system could be presented as below:

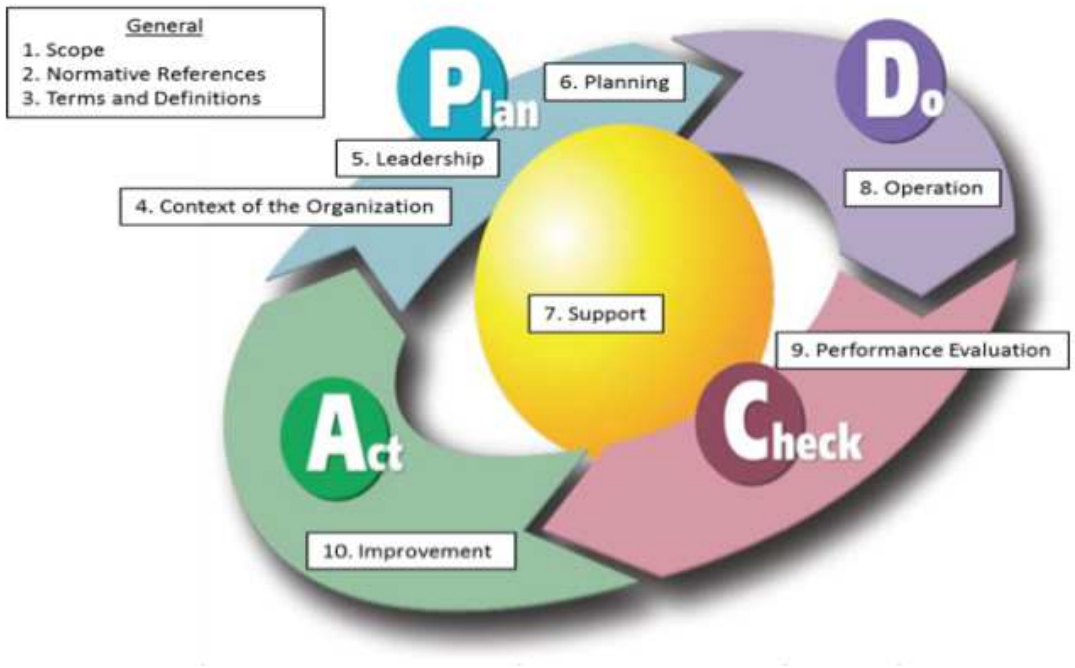


Figure 5.10: Framework of the ISO 55001 Management System Standard using the PDCA

The first phase is concerned by all the planning aspects. It starts from the comprehension of the internal and external context of the ETMU. The strategic study has focused on the electric transmission field at STEG and led to a SWOT analyses.

Adaptation to the ETMU's case was necessary and consequently a little adjustment was done by:

- Determining the ETMU’s stakeholders and their requirements
- Delimiting the asset portfolio managed by the ETMU
- Determining the allocated responsibilities for each team within the unit

Two assumptions were considered:

- The ETMU executes only maintenance activities on transmission assets
- The activities that has important impact on assets are not outsourced

Once the Asset management scope is delimited and basing on the strategic study, the ETMU could edit its:

- Asset management policy
- Asset management strategy
- Asset management objectives

All previous activities and their outputs shall be edited and mentioned within the Strategic Asset Management Plan (SAMP). The SAMP is a requirement of ISO 55001:2014.

The second phase tries to transform the SAMP to activity plans. The organization shall establish an Asset management plan (s). This is the second document requirement.

The asset management plan comprises and plans a set of activities that aim to fulfil the SAMP.

However, before planning those activities, Asset management emphasizes on establishing a risk evaluation process. This process tries to identify, evaluate, record and plan actions against risks coming from assets and assets management.

A process that was done by a workgroup within STEG and that its output fit with ETMU. A little adjustment was necessary. The executed work was activities focused and an asset failure risk assessment was added.

The output of this work is the Assets risk register.

The Asset risk monitoring and management is an ongoing process and a requirement of ISO 55001[43]. The ETMU shall establish a risk process during all phases of the PDCA cycle.

The edition of the Asset management plan should be an iterative process interacting with risk process and also resources process and of course the improvement process.

The ETMU plan should comprise

- Justification of the asset management activities
- Maintenance plan
- Resources and capital investment plan

The maintenance plan does not exist in the ETMU. The already existed plan in the CMMS data base is not optimized and not risk assessed.

[43] Clause 6.2.2

The resources and capital investment plan already exist, however there is no time scheduling, no effective cost estimation... so forth. A process of establishing and updating the asset management plan should be created and documented.

The Asset management plan could be sustained by resource management process, communication management process, competence management process, information management process. All those processes should be established and documented in the ETMU.

Business process establishment, description, documentation and mapping is missing within the ETMU and it is compulsory for the operation phase and the monitoring phase.

Data and information management is also a great concern of the asset management system. A review of asset required information, asset activities required information and asset management system required information should be done. ETMU does not have an clear scoreboard that fit to its requirements and that take account of the stakeholders needs.

Key performance indicators are really necessary for asset management performance evaluation and impact risk assessment and improvement processes. Information management is a main pillar is asset management and a key driver during the decision making process.

Obviously the ETMU shall also establish internal audit process; a management review process, and improvement processes. The main remark is that the enumerated processes are common to many management systems and particularly to Quality management.

Considering that many other units are ISO 9001 certified, ETMU could import and adjust those process and related procedures and practices to its context.

The Annex is a draft of an implementation plan that could be presented to top management in order to argue the feasibility of the establishment of the asset management system and preparing the certification. Actually, according to [Botha; 2014], “Very soon insurers, regulators, clients and shareholders will start to make ISO 55000 certification a prerequisite for doing business, much like what happened to ISO 9000 or ISO 14000.”

Conclusion

The Tunisian Company of electricity and gas (STEG) is the dominant actor of the Tunisian market and the historical supplier of electricity in Tunisia. STEG is a vertically integrated company and, until now, it is a monopoly in the transmission field. However, upheaval changes in STEG's context, such in government policy, regulation, technologies, in economy... so forth; lead to review the organization strategy.

In this paper, we are particularly interested to the transmission strategic business unit. A conventional strategic study demonstrated that, basing on generic Porter's strategies, the best solution is adopting a cost focus strategy. However, a 'one-size-fits-all' approach is definitely out of the question. A broader investigation and taking account of electricity transmission field specificities. Actually electricity transmission is an asset-intensive business with a wide assets geographic spread. The use of grid techniques and the international interconnections with neighbouring countries increase risk levels and constraints. As a result the cost focus strategy should make the trade off with requirements of technical performances.

The strategy shall seek for the optimization of expenditure, productivity and performance of assets to achieve core business objectives.

The second concern is about finding the best trade off between the top-down aspiration and bottom-up daily issues. How to find the line of sight between all management levels? How an operational unit, as ETMU, could execute its daily tasks and complying with STEG's strategic guidelines.

At this stage, Asset management appears as the best solution, and the establishment of such management system as a strategic decision. The asset management is widely used in English-speaking countries, such the UK, USA, Canada, Australia, and New Zealand and It is commonly used within eclectic utilities.
Asset management has appeared in Australia in the 1980's. It was formalized by the British Standard Institute in 2004 with PAS 55:2004 and reviewed with PAS 55:2008. However, asset management could be considered as a breakthrough in business management yet. Even more, it was recently adopted and released in 2014 under the label ISO 55000 series.

Dealing with the whole life cycle of assets and the related activities, establishing such system seems to be a huge task. The ETMUs deals just with maintenance side while the asset management is more convenient for the overall organization or at least the transmission department, and focuses on assets from acquirement until disposal. However, as a big company, introducing change is generally faced by big fears and resistance. For big inertia corporation, an iterative change process it could be a good solution. The first stage will be the implementation of an asset management system within the ETMU.

The ISO 55001 provides a standardized framework for the establishment process. Following its requirements, new concepts could be introduced within the unit like the notions of assets, asset systems and a portfolio of assets. The link between asset management and the business strategy is established and communicated through the strategic planning documents (the asset management policy, strategy, objectives and plans). The concept of risk management is also

introduced and integrated. The concepts of stakeholders' care, communication, evaluating performance and analyzing data or information are totally new. The continual improvement concern is also expressed with management reviews and audits.
During all the processes, ISO emphasizes on balancing asset-related measures between risk reduction, cost reduction and performance improvement. This paper tries to show the feasibility of the implementation within the ETMU. Suggest an implementation plan that skims through the needed actions. This plan is just a draft and should be improved through an iterative process and with the participation of main actors in the ETMU.

Finally, the asset management is not a silver bullet, but a set of good practices in order to control the actual situation, to drive improvements, to keep harmony between all management levels and obviously the finality is to achieve the corporate objectives.

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