PGESCo

Engineering Magazine

Issue 35 December, 2020

EGYPT SMARTGRID CAIRO REGIONAL CONTROL CENTER (CRCC)

.... p4

Editor's Note..

I'm delighted to present this issue for you, which will be the last time for me to that before my final retirement on December 31st.

We have been able in the past three month to discuss, follow up, and receive three excellent articles that I hope one or more of them will enjoy reading them.

The first article by Dr. Wael Yousef and Eng. Ehab El Metwally titled **"EGYPT SMART GRID ... CAIRO REGIONAL CONTROL CENTER CRCC".** The article shed lights on Egypt's activities for Smart Grid Technology that is linked to the new project of CRCC, and PGESCo contribution in this projects.

The second article by Dr. Atef El-Sadat titled **"PARAMETRIC STUDY OF TALL RC CHIMNEYS USED IN EGYPTIAN POWER PLANTS SUBJECTED to LATERAL LOADS"** This paper investigates the behavior of tall reinforced concrete chimneys subjected to lateral loads due to wind and seismic loads. The main objective of the study is to identify the influence of the investigated slenderness ratio (Height/ Diameter) on the static and dynamic behavior of the chimney under lateral loads.

The third short paper by Eng. Moataz Khalifa titled **"SELECTION CRITERIA OF WASTEWATER TREATMENT TECHNOLOGIES"** the article summarizes how Planning and implementation of wastewater treatment systems comprises many aspects not only the technical requirements but includes other non-technical aspects that are contributing on the technology selection.

I hope you enjoy reading PGESCo Engineering Magazine, with my best wishes for your endeavor in your current and future life.

GOOD BYE .....

Dr. Mohamed ElBanhawy.

In This Issue

The Magazine Cover about

>>>> Egypt SmartGrid

EGYPT SMARTGRID CAIRO REGIONAL CONTROL CENTER (CRCC)

Article By : Dr. Wael Youssef,
Ehab El Metwally

Introduction to SmartGrid

A smart grid is an electrical grid that uses 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. Smart grids are now being used in electricity networks, from the power plants all the way to the consumers of electricity in homes and businesses. The “grid” amounts to the networks that carry electricity from the plants where it is generated to consumers. The grid includes wires, substations, transformers, switches etc. The major benefits are significant improvement in energy efficiency on the electricity grid as well as in the energy users’ homes and offices [1].

Why Smart Grid?

In a typical smart grid Fig. 1, central management center controls all the units connected to it making sure to operate them at the highest efficiencies. The central management center does not only assist in better energy management inside the facility but also it helps in reducing the electrical consumption during peak times. This reduction is reflected as huge energy savings.

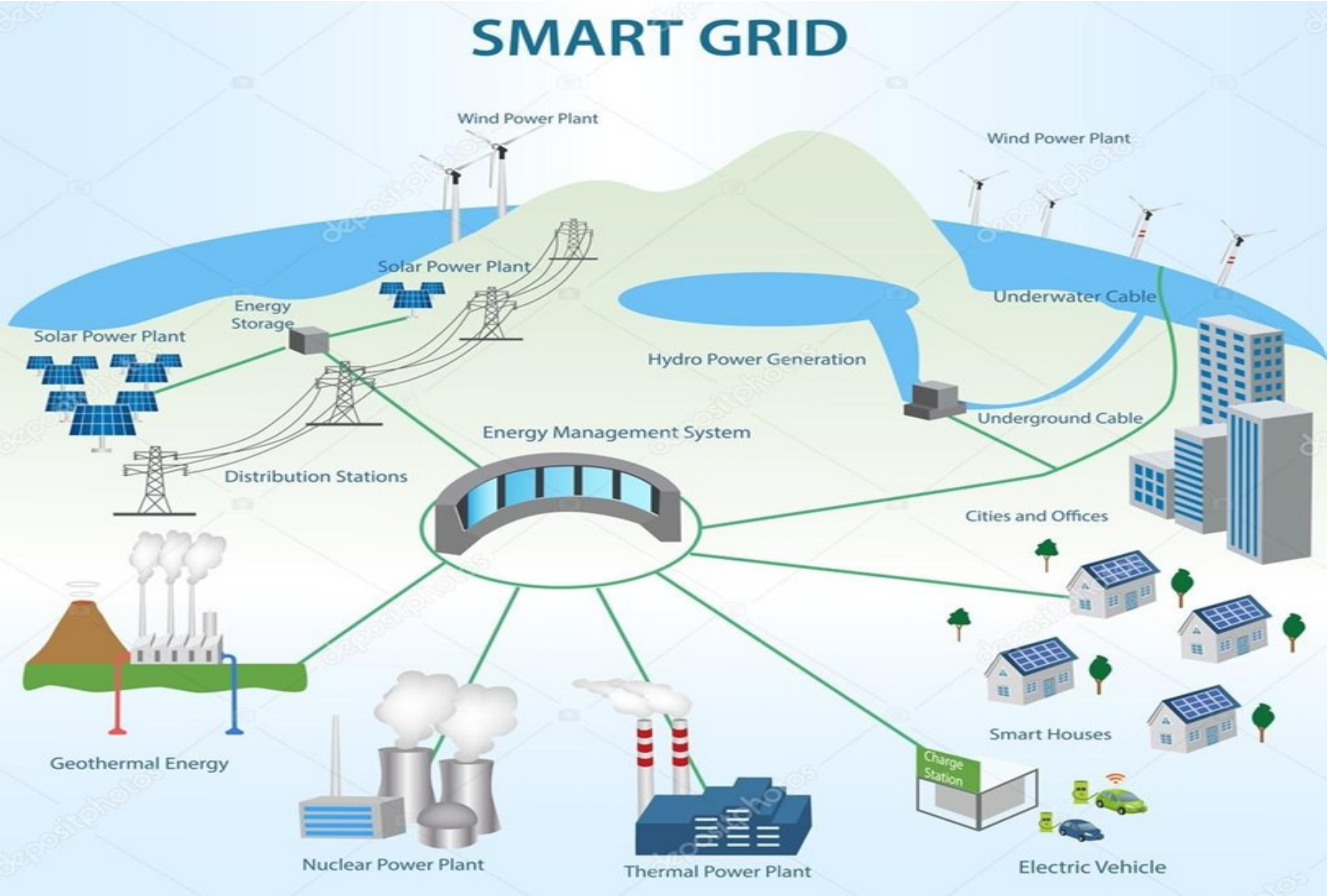


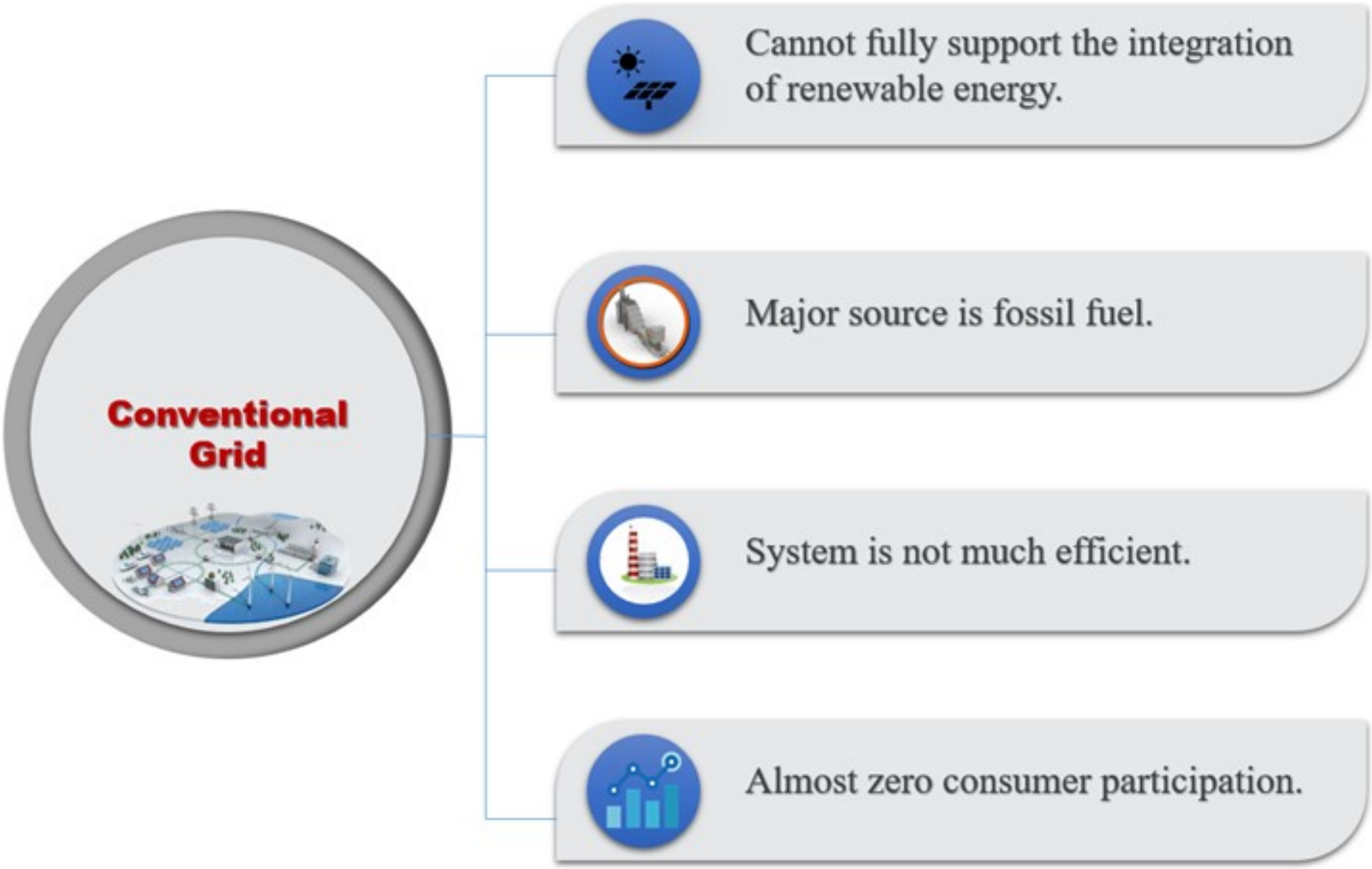
Fig. 1 Typical Smart Grid

A smart grid also facilitates switch from conventional energy to renewable energy. In case of having a source of renewable energy in the facility, the grid allows an easy access to integrate it into the grid. Smart grid permits greater penetration of highly variable renewable sources of energy, such as wind power and solar energy.

Smart grid is a new gateway to a green future. It not only provides better energy benefits but also opens up new avenues of employment for youngsters. For example, conversion of normal operating units into smart ones capable of connecting to the smart grid is full of new and exciting opportunities. The global market for smart instruments is trending up with out-of-the-box ideas and innovations from young energetic minds [2], [4].

Conventional Grid

Today's grids were built to accommodate centralized generators, unidirectional electricity transport through high-voltage transmission lines, dispatch to consumers via lower-voltage distribution feeders, and centralized control centers collecting information from a limited number of network hubs, called substations as show in Fig. 2. The goal of such power grids is to optimize, for a given combination of power plant fleets and consumer- demand pattern, both reliability (the frequency and extent of outages) and quality of power supplied (in terms of voltage signal shape, frequency and phase angle) at a minimal cost [4].



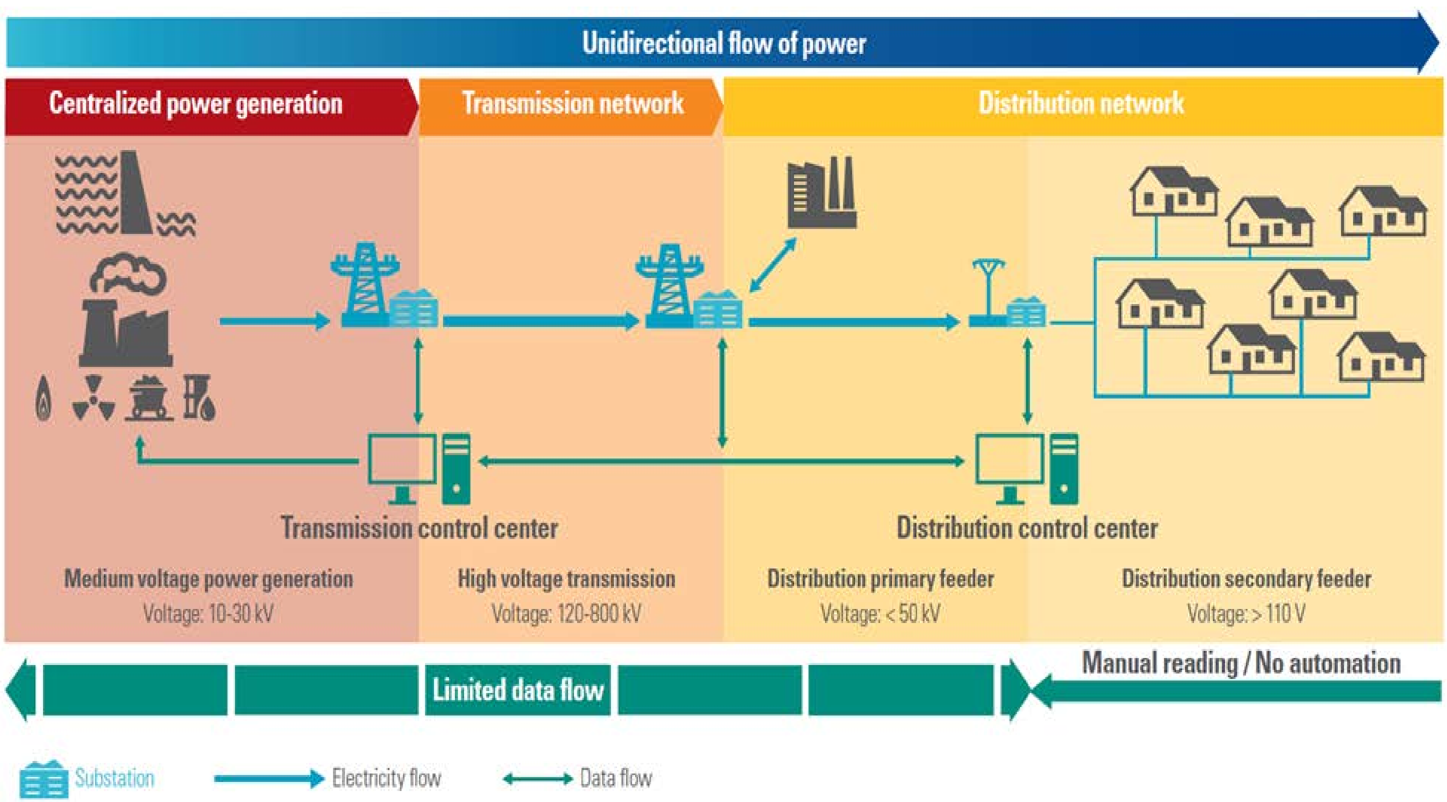


Fig. 2 Simplified View of the Conventional Grid

Key differences between traditional and smart grids:

Area	Traditional grid	Smart grid
Communication	Electromechanical	Digital
	One-way	Two-way
Power	Centralized	Centralized&distributed
Monitoring & control	Few sensors	Sensors throughout
	Manual monitoring	Self-monitoring
	Manual restoration	Self-healing
	Failuresandblackouts	Adaptive & islanding
	Limited control	Pervasive control
Market	Fewcustomerchoices	Many customer choices

To fulfil this purpose, grids must be able to accommodate all generation and storage options, optimize energy efficiency and asset utilization, improve power quality for end-user devices, self-heal, resist physical and cyber-attacks, and enable new business solutions in a more open-access electricity market, such as demand-response programs and virtual power plants.

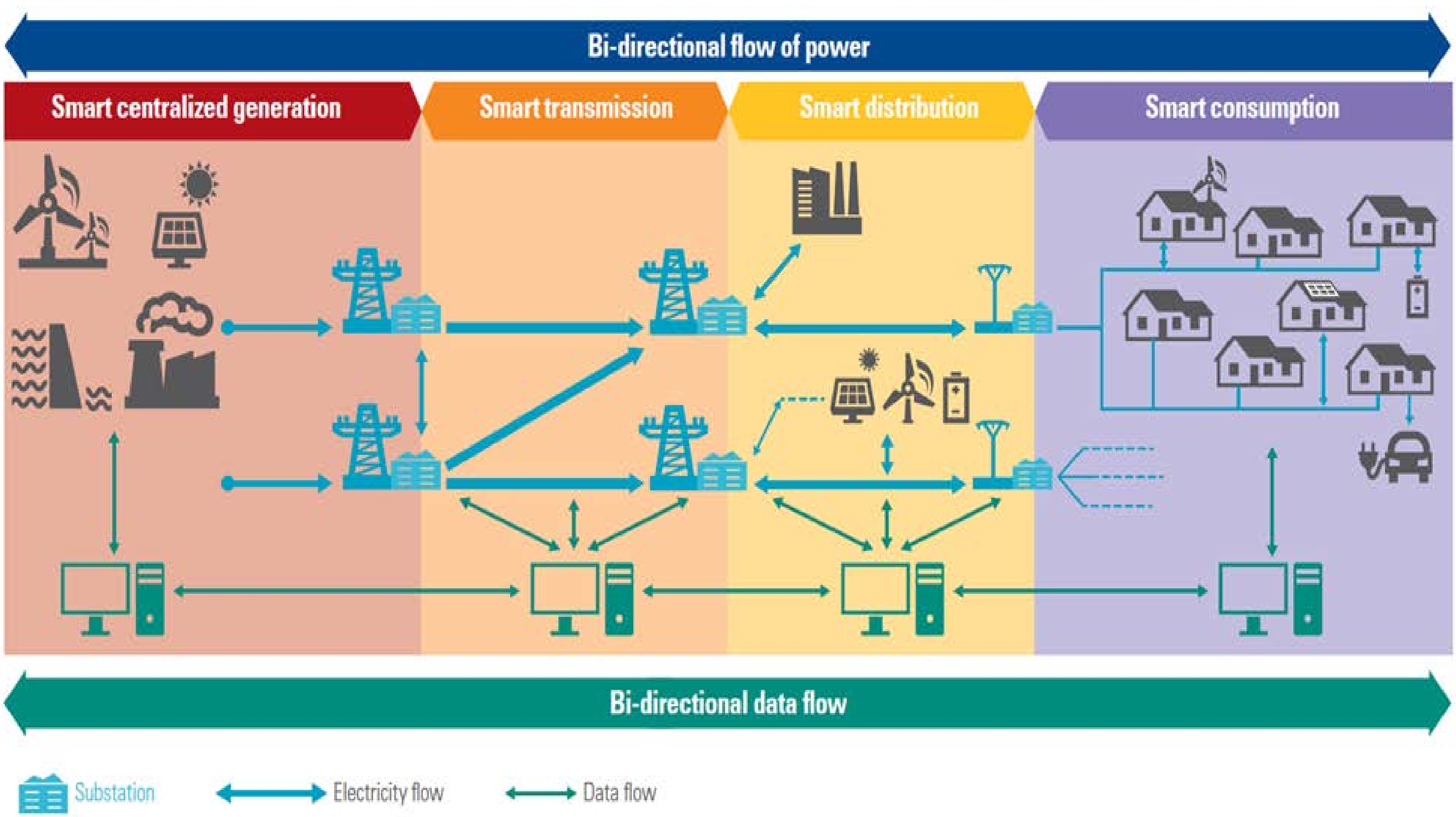


Fig. 3 Simplified View of the Modernized Grid

Beyond incremental changes in traditional grids, smart grids facilitate the expansion of independent micro-grids that are capable of "islanding" themselves from the main grid during power-system disruptions and blackouts. The modular nature of micro-grids may allow for their independence, interconnection and, ultimately, the construction of a new type of super-reliable grid infrastructure. Fig. 4 shows Smart grid benefits by technology application and related grid challenges.

Existing grid challenges	Enhance physical network	Optimize grid monitoring & control	Enable active customer contribution
Rising and intensifying electricity demand	**Increase power-line capacity** via electronic devices and sensors installed along the lines (DLR, FCL, FACTS, CVR…)	**Predict and optimize electricity flow** via new sensors and algorithms of higher spatial and temporal granularity, and Wide-Area Monitoring & Control (WAMC, PMU…)	**Flatten aggregated peak demand** via dynamic demand-response programs
Aging infra-structure (losses & unreliability)	**Reduce transport losses** by using more efficient cables (HVDC, superconductors…)	**Improve power reliability** via smart protection systems, both in anticipation (failure prediction algorithms and condition-based maintenance), and in reaction (distribution automation, self-healing grid, FDIR)	**Track down thefts** via advanced metering infrastructure
Increasing share of Variable Renewable (VRE)	**Connect offshore wind-farms** via subsea HVDC cables	**Smooth variability of VRE output** by enlarging grid inter connections via Wide-Area Monitoring & Control	**Provide additional flexibility means** by pooling of customers into virtual power plants that can store or supply large amounts of electricity in a dispatchable manner
Increasing share of Distributed Generation (DG) & Electric Vehicles (EV)	**Achieve customer energy savings** by stabilizing voltage delivered to end-users as closely as possible above nominal values, optimizing appliance efficiency (CVR)	**Preserve power quality** by absorbing voltage instability caused by back-flows of electricity or re-synchronization of islanded micro-grids thanks to voltage control (VVC, capacitor banks, PMU…)	**Incentivize DG and EV deployment** via net metering programs and vehicle-to-grid technologies, which turn individual customers in to local suppliers of electricity

Fig. 4 Smart grid benefits by technology application and related grid challenges

Transition to Smart Grid

The transition to a smart grid requires the deployment of new power infrastructure, electronic devices and computer systems, interconnected via high-speed communications networks, using standardized protocols. Fig. 5 covers the most important smart-grid technologies, which can be segmented into three main categories of application.

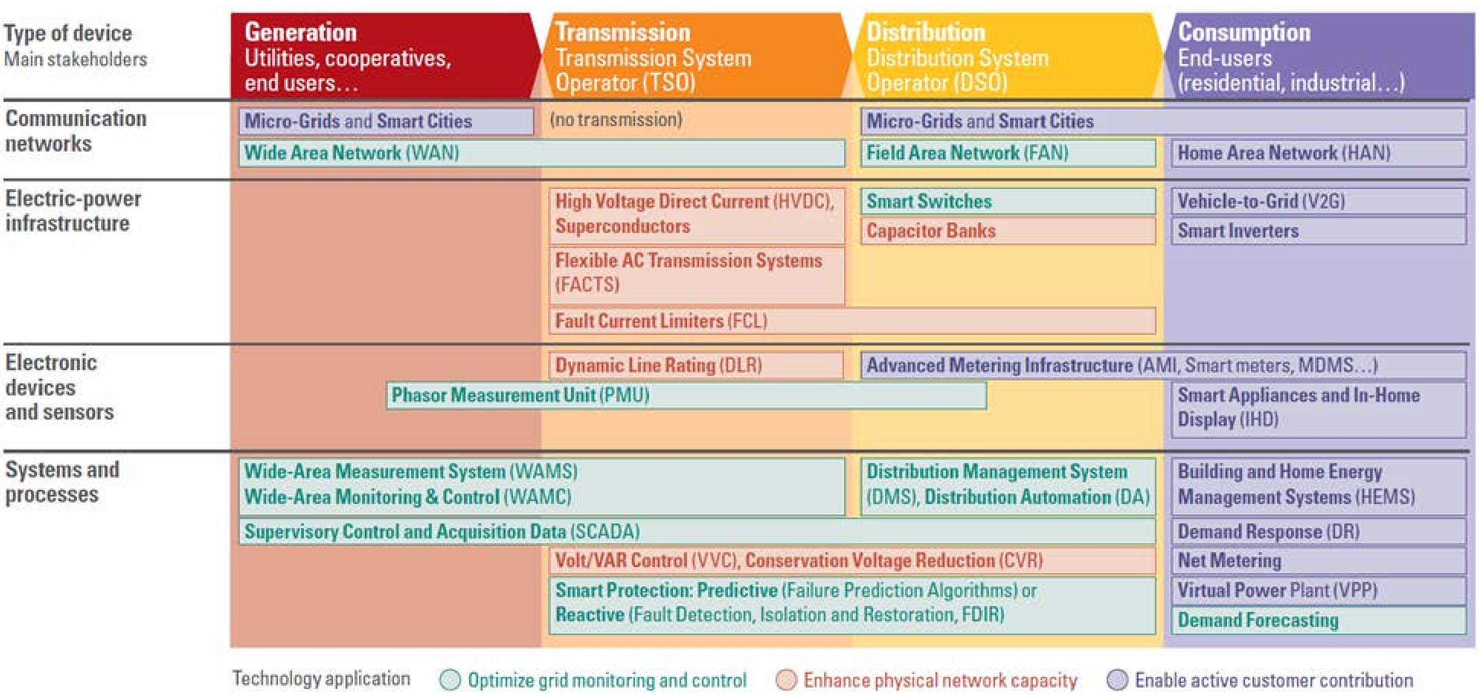


Fig. 5 Smart Grid Technology

A. Grid Monitoring and Control Optimization

The first application involves the optimization of grid monitoring and control, with advanced sensors and IT solutions interconnected via modern communications networks in Wide-Area Monitoring & Control (WAMC) or Distribution Automation (DA) systems. Such systems enhance control over dispatchable power plants; improve routing of electricity flows; anticipate demand patterns or grid weaknesses by virtue of predictive algorithms and condition-based maintenance; react automatically to incidents threatening the reliability of power supply with the use of smart reclosers, which make distribution grids self-healing.

B. Enable Active Customer Contribution

The second purpose of smart grids is to enable consumers to contribute to grid management through the medium of intelligent end-user devices. Combining advanced metering infrastructure with smart appliances makes dynamic demand- response programs possible. These can contribute to system flexibility (in addition to peaking power plants or electricity storage) to compensate for fluctuations in VRE output or to flatten out aggregated peak loads. Bi-directional smart meters enable net metering and vehicle-to-grid programs that incentivize individual customers to become local suppliers of power and storage capacity. In addition, automated meter readings reduce the operating costs of distribution-system operators and provide greater visibility into pilferage.

C. Enhance The Physical Capacity

The third principal aim of smart-grid technology is to enhance the physical capacity of the network. Ultra-high voltage lines, direct-current underground cables or superconductors transport more power with lower energy losses and a smaller visual footprint than conventional power lines. These new technologies could be especially effective in connecting remote offshore wind farms to distribution grids or interconnecting asynchronous grids. Finally, the maximum admissible power throughput of existing lines could also be dynamically enhanced by installing along them special temperature sensors, voltage or current control devices. This would allow the deferral of expensive and sometimes- controversial grid-extension plans [5].

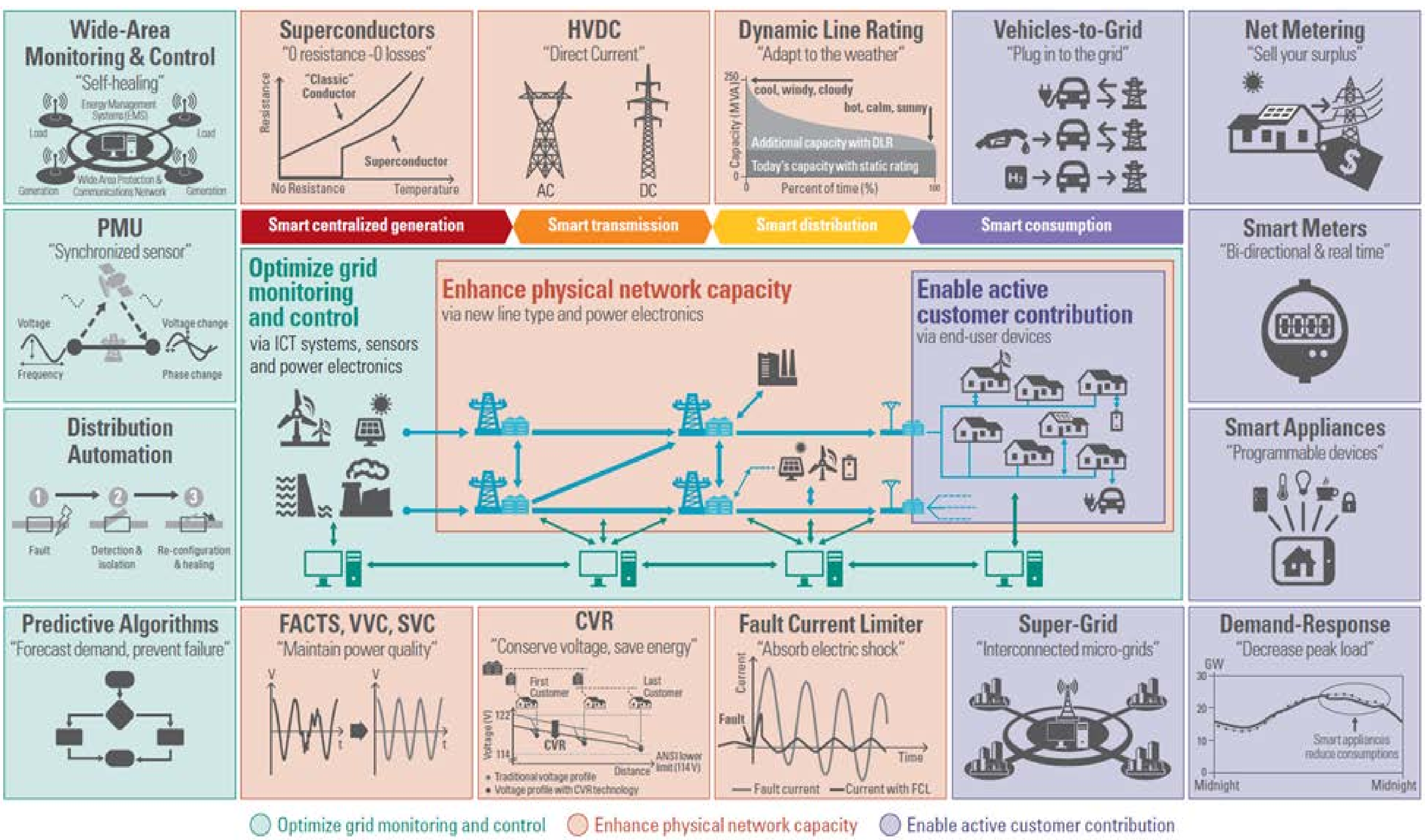


Fig. 6 Smart Grid Technology

First Step to SmartGrid in Egypt (CRCC)

Cairo Regional Control Center position in EETC Network

- Control Centers are established to keep up with the requirements of the stable, safe, and effective operation of the Power Network
- National Energy Control Center (NECC) is responsible of monitoring and control of the Extra High voltage 500 kV & 220 kV transmission networks and generation all over the country as well as managing power exchange between neighboring countries
- Regional Control Centers (RCCs) collect necessary information from its relevant 500 kV, 220 kV and 66 kV substations
- They act as a backup for the (NECC) for 500 kV and 220 kV networks besides, they are responsible for the monitoring and control of 132 kV and 66 kV networks

Regional Control Centers in Egypt

- The boundaries of the RCCs extend up to the 11 kV ad 22 kV level in the distribution network
- There are six regional zones:
- Cairo RCC (established 2002)
- Canal RCC (established 2000)
- West Delta RCC (established 2007)
- Middle Egypt RCC (established 2018)
- Upper Egypt RCC (established 2018)

Objectives of the CRCC Upgrade

- Achieving effective monitoring and controlling of the 66/11 kV (22 kV) substations and their transmission network in 3 Governorates (Cairo, Giza and Kalioubia)
- Faster identification of tripping or faults leading to quicker restoration of supply
- Reduced Outage duration leading to consumer satisfaction and lower loss of revenue to the utility
- Accurate online calculation of system loads and peak load on daily, weekly, monthly or yearly basis

Scope of the CRCC Upgrade Project

The upgrading of CRCC includes monitoring, managing and control of the 66 kV transmission network and associated 66/11(22) kV substations. Also monitoring 220 kV & 500 kV transmission network in the Great Cairo area which serves about 23 million people in three Governorates (Cairo, Giza and Kalioubia).

The existing CRCC building is located in Cairo North area.

The project includes the following main Systems:

- SCADA /EMS system , Remote Terminal Units (RTUs), Adaptation work at substations
- Communication System which is comprised of:
- Modern communication system based on MPLS-TP Technology for Voice & Data transmission Network, including network management system and the ICCP (International Control Centers Protocol) data links to the other Control Centers
- Telephone System with VOIP Technology together with voice recording system
- 48 V DC system as may be needed
- Fiber Optics Cables with accessories (OPGW/ ADSS/ UG) as Communication Media to replace and/or existing F.O. Cables over specified routes

Fig. 7 Cairo Control Center

- Rehabilitation and Upgrading of the existing Control Center facilities include but not limited to painting, raised floor, suspended false ceiling, UPS system, security intruder system, access control, HVAC system and Building Management System (BMS).

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2) Ilhami COLAK, Ramazan BAYINDIR, Seref SAGIROGLU, "The Effects of the Smart Grid System on the National Grids", Smart Grid (icSmartGrid) 2020 8th International Conference on, pp. 122-126, 2020.

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4) Yehia Zakari, “The Smart Grid Evolution, Introduction and Survey for the Related Topics”, PGESCo Engineering Magazine, Issue 10, Sept. 2014.

5) ATKeaney, “Introduction to Smart Grids Beyond Smart Meters”, Energy Transition Institute, 2015.

Author Biography:

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Ehab El Metwally: earned BSc. in Electrical Engineering, department of Communications and Electronics from Ain Shams University Egypt, in 1998 and MSc. from the same department and university in 2005. He has nine years of experience in engineering of communication systems in addition to seven years of experience in high voltage substations protection, communication and automation. He is interested in power automation and smart grid applications. He is currently working as a Telecommunication and substation Automation Systems Specialist in PGESCo

PARAMETRIC STUDY OF TALL RC CHIMNEYS USED IN EGYPTIAN POWER PLANTS SUBJECTED TO LATERAL LOADS

Article By : Dr. Atef El Sadat

1 Introduction

A chimney is a structure that provides ventilation for hot flue gases or smoke from a boiler, stove, furnace or fireplace to the outside atmosphere. Chimneys are typically vertical, or as near as possible to vertical, to ensure that the gases flow smoothly, drawing air into the combustion in what is known as the stack or chimney effect. It safeguards people at or close to the plant from high concentrations of those pollutants by providing dilution of the pollutants in the atmosphere.

The design of a tall chimney, as being slender structure, is very sensitive to wind and seismic forces. The American code ACI 307-08 [1] is, in most of the Egyptian Power Plants, considered as the reference code for the chimney design. Consequently, all used equations are in imperial units (mile, foot, inch, pound and kip) then the output value is converted to metric units (km, m, mm, kg and tons).

This paper investigates the behaviour of tall reinforced concrete chimneys subjected to lateral loads due to wind and seismic loads. The main objective of the study is to identify the influence of the investigated slenderness ratio (Height/ Diameter) on the static and dynamic behaviour of the chimney under lateral loads. Staad Pro V8i [12], developed at Bentley systems Inc., has been used to simulate the full-scale chimney model to study its static and dynamic behaviour.

Staad Pro V8i [12] is a 3D structural analysis and design software which can make use of various forms of analysis from the traditional 1st order static analysis, 2nd order p-delta analysis, geometric non-linear analysis, Pushover analysis (Static-Non Linear Analysis) or a buckling analysis. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis.

In the last decades, many of thermal power plants have been constructed in Egypt using the latest thermal technology in turbines and boilers to achieve the maximum efficiency with the minimum fuel consumption. These types of power plants require very tall concrete chimneys to deliver the exhaust in a certain height that is acceptable by the environmental regulations. Among these thermal power plants were El-SUEZ, El-SOKHNA and SOUTH HELWAN plants. Each one of these power plants requires a concrete chimney with a certain height and diameter.

In the parametric study, El-Suez Power Plant was chosen to perform the parametric study either by changing the height and fixing the diameter, or by changing the diameter and fixing the height. It is intended to choose a realistic case to simulate realistic chimney dimensions from actually constructed chimneys. The parametric study is aiming to determine the optimum shell thickness and its corresponding reinforcement ratio for a certain chimney height and diameter with a welldefined wind and seismic parameters. Also, a flowchart summarizing the chimney design process is presented.

This work is a part of a more extensive research program conducted by "El-Sadat, A." [3]. However, additional researches can be conducted to study and compare the design of R.C chimneys using different codes (American code, European code, British code, CICIND code, etc...) and may introduce the effect of foundation and soil interaction in the study.

2 El-Suez Chimney Description

El Suez Power Plant is located near El-Suez city directly on the red sea. The reinforced concrete chimney, with the height of 152.0 m and outside diameter of 11.50m, is used to exhaust combustion products from 1x650MW gas/oil fired steam turbine unit.

2.1 Chimney Input data

Height of the chimney: 152.0 m above terrain level; External diameter of the stack at the bottom: 11500 mm; External diameter of the stack at the top: 11500 mm

Number of Flue gas duct: 1; Internal diameter of the of Flue gas duct (F.G.D): 8040 mm;

Material of the stack: Concrete 4500 psi (32.0 MPa) & reinforcing steel grade 60 (ASTM A615); Material of lining supporting slabs: Concrete 4500 psi (32.0 MPa) & reinforcing steel grade 60 (ASTM A615); Openings: 2 x Flue gas ducts 3600 x 8050 mm & 2 x Main door openings 3000 x 4500 mm; Max. Flue gas temperature: 155 to 160°C.

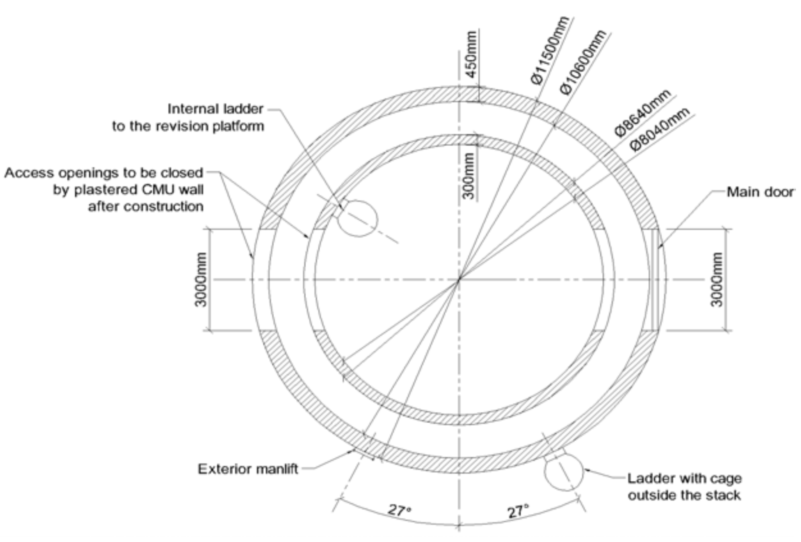

Fig. 1 Chimney sectional plan at bottom level

3 Chimney Loading

3.1 Chimney gravity load

Gravity loading is given by geometric and material characteristics of elements. Specific weight for reinforced concrete is 25 kN/m^3. Loading includes own weight of concrete wind shield. Liner weight is given by 105 mm thickness, inner diameter 8040 mm and specific weight of the shaped bricks 21.1 kN/m^3.

3.2 Chimney wind load

Wind induced forces on buildings depend on several parameters, such as the building's shape and height, the nature of upwind terrain, the influence of nearby structures and the structural properties of the building (mass, stiffness and damping). The wind resistant design of chimney is to be carried out after taking into account the along-wind load, across-wind load and aerodynamic interference effects. The present trend is to consider wind load as the sum of the two components. One is caused by the mean wind speed and the other by the fluctuating wind gust. The mean wind load contribution is proportional to the square of the reference wind speed. The dynamic component is evaluated using gust factor approaches; which depend upon the natural frequency, damping, geometric properties of the chimney and the Reynolds number.
In addition, the hollow circular cross section shall be designed to resist the loads caused by the circumferential pressure distribution.

The reference design wind speed denoted as V_r shall be computed as follows:

$$V_r = (I)^{0.5} \times V = 144.77 \quad (1)$$

Where; V Basic wind speed, taken 135 km/hr

I importance factor, all chimneys are taken as 1.15

All values of mean and fluctuating wind loads are shown in the following table, including moment at chimney bottom. The chimney is divided into 24 sections, each section is about 6.38m high.

Table 1: Fluctuating and summed wind load evaluation

Section	Height of lower edge above ground (m)	z Height in center of the section above ground (m)	*d(z)* Outside diameter of chimney in the lower end (m)	$p(z)_{mean}$ Pressure due to mean hourly design wind speed at height z (kPa)	$w(z)_{mean}$ Mean along-wind load at height z (kN)	$M_W(b)$ Bending moment at base due to mean along-wind load $w(z)_{mean}$ at height z (kN.m)	*w'(z)* Fluctuating along-wind load at height z (kN)	*w(z)* Total nominal along-wind load at height z (kN)	Nominal bend.moment at the lower edge of the section (kN-m)	Design bend.moment at the lower edge of the section (kN-m) * 1.6
1	145.63	148.81	11.50	0.92	73.9	11004	65.9	139.8	**446**	**713**
2	139.25	142.44	11.50	0.90	73.0	10392	63.1	136.0	**1771**	**2833**
3	132.88	136.06	11.50	0.89	46.8	6362	60.2	107.0	**3870**	**6192**
4	126.50	129.69	11.50	0.88	46.1	5975	57.4	103.5	**6640**	**10624**
5	120.13	123.31	11.50	0.87	45.4	5594	54.6	99.9	**10059**	**16094**
6	113.75	116.94	11.50	0.85	44.6	5218	51.8	96.4	**14103**	**22566**
7	107.38	110.56	11.50	0.84	43.9	4850	48.9	92.8	**18751**	**30002**
8	101.00	104.19	11.50	0.82	43.1	4487	46.1	89.2	**23979**	**38366**
9	94.63	97.81	11.50	0.81	42.2	4131	43.3	85.5	**29763**	**47621**
10	88.25	91.44	11.50	0.79	41.4	3783	40.5	81.8	**36081**	**57730**
11	81.88	85.06	11.50	0.77	40.5	3442	37.7	78.1	**42909**	**68655**
12	75.50	78.69	11.50	0.75	39.5	3108	34.8	74.3	**50223**	**80357**
13	69.13	72.31	11.50	0.73	38.5	2783	32.0	70.5	**57999**	**92798**
14	62.75	65.94	11.50	0.71	37.4	2467	29.2	66.6	**66211**	**105938**
15	56.38	59.56	11.50	0.69	36.3	2159	26.4	62.6	**74836**	**119737**
16	50.00	53.19	11.50	0.67	35.0	1862	23.5	58.6	**83846**	**134154**
17	43.63	46.81	11.50	0.64	33.7	1576	20.7	54.4	**93217**	**149147**
18	37.25	40.44	11.50	0.61	32.2	1301	17.9	50.1	**102921**	**164673**
19	30.88	34.06	11.50	0.58	30.5	1040	15.1	45.6	**112929**	**180687**
20	24.50	27.69	11.50	0.55	28.6	793	12.3	40.9	**123213**	**197141**
21	18.13	21.31	11.50	0.50	26.4	563	9.4	35.9	**133742**	**213988**
22	11.75	14.94	11.50	0.45	23.7	354	6.6	30.3	**144482**	**231171**
23	5.38	8.56	11.50	0.38	19.9	171	3.8	23.7	**155394**	**248630**
24	-1.00	2.19	11.50	0.25	13.1	29	1.0	14.1	**166426**	**266282**

Across wind loads due to vortex shedding in the first mode shall be considered if critical wind speed V_{cr} is between 0.50 and 1.30 $\overline{V}$ (z_{cr}), where $\overline{V}$ (z_{cr}) is the mean hourly wind speed at (5/6)h. Across-wind response in second mode shall be considered if critical wind speed V_{cr2} is between 0.50 and 1.30 $\overline{V}$ (z_{cr}). Analysis, performed according to ACI 307-08 [1], proved that all across-wind effects can be neglected.

3.3 Chimney seismic load

Input data for seismic calculation:

Occupancy category III, Table 1.1 [2]; Seismic importance factor Ie = 1.25, Table 9.1.4 [2];

Site class D; Spectral response acceleration at short periods S_S = 0.417

Spectral response acceleration at 1 second periods S_1 = 0.106; 5% damped design spectral response acceleration at short periods S_{DS} = 0.408; 5% damped design spectral response acceleration at 1 second periods S_{D1} = 0.168; Seismic design category SDC = C, Table 9.4.2.1(a) or Table 9.4.2.1 (b) [2] whichever results in the most severe category. The response modification factor R shall be taken as 1.5 [1].

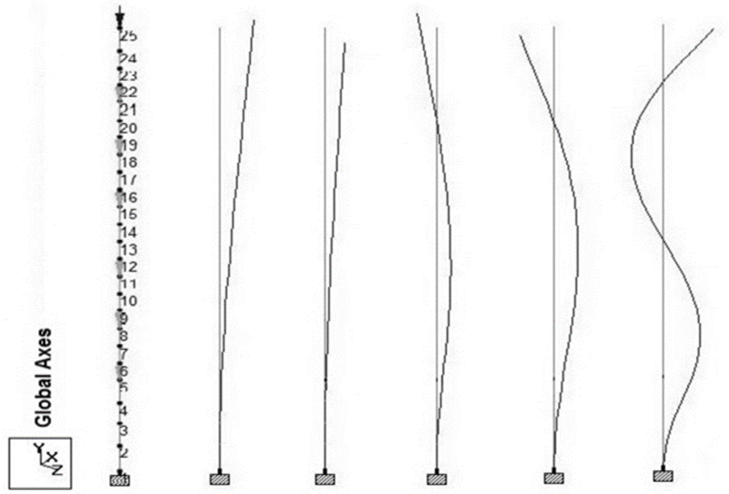

Fig. 3 Simplified seismic beam model with the first 5 mode shapes and beam local axes

Simplified beam model is used in this case to compute bending moments along the chimney height. Model has 24 beam elements; STAAD Pro V8i [12] is used to carry the response spectral analysis.

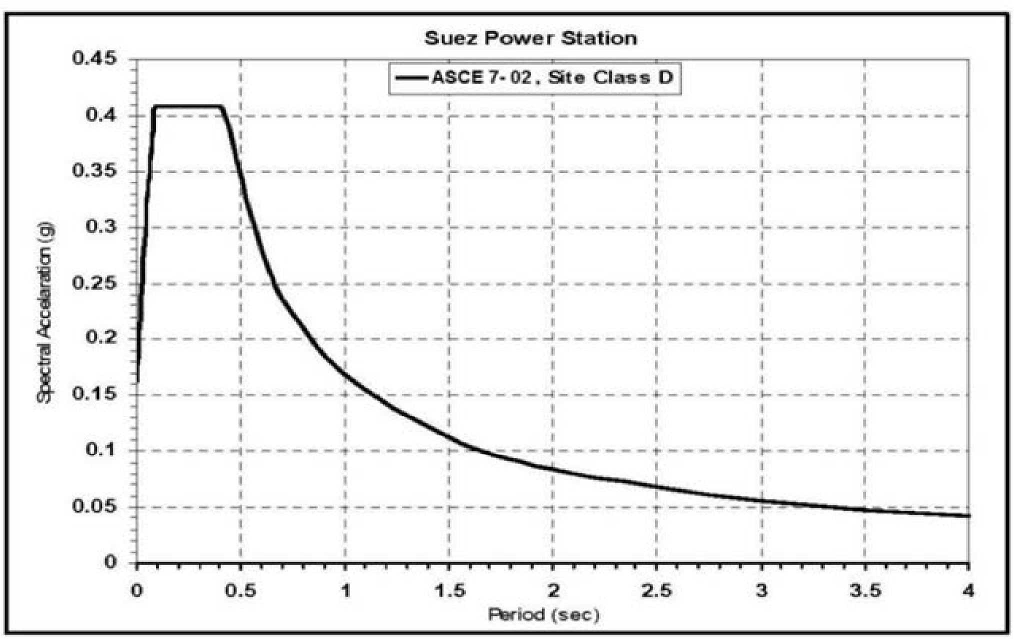

Fig. 2 Design Acceleration spectrum for site class D for El-Suez Chimney Site

Table 2: Beam end force summary for seismic

				Axial	Shear		Bending	
	Beam	Load combination	Node	Fx (KN)	Fy (KN)	Fz (KN)	My (KNm)	Mz (KNm)
Max Fx	1	L.C. 10 (1.4 DL)	1	**75,404**	0	0	0	0
Max Fy	1	L.C. 11 (1.2 DL + 1.0 EX)	1	64,632	**3,359**	1,088	21,894	182,351
Max Fz	1	L.C.12 (1.2 DL+1.0 EZ)	1	64,632	1,088	**3,359**	182,351	21,894
Max Mx	1	L.C. 10 (1.4 DL)	1	75,404	0	0	0	0
Max My	1	L.C.12 (1.2 DL+1.0 EZ)	1	64,632	1,088	3,359	**182,351**	21,894
Max Mz	1	L.C. 11 (1.2 DL + 1.0 EX)	1	64,632	3,359	1,088	21,894	**182,351**

4 Parametric study

El-SUEZ chimney with the height of 152m and slenderness ratio of 13.2 is chosen for the required study. Comparing the results of the ultimate base moment at the chimney bottom section from wind load (266,282 kN.m) and from seismic load (182,000 kN.m), it's obvious that the wind load shall always govern the design for tall chimneys especially in low and moderate seismic zones. No need to perform seismic analysis in the parametric study as the wind loads should usually control the design of the chimney section. Wind loads shall be calculated statically according to ACI 307-08 [1] equations, then the fundamental period, local stresses around openings and deflection at the top of chimney is computed by using a 3D finite element software (Staad Pro V8i [12]).

4.1 Basic schemes of the model

The chimney shell model was created according to the next principles:

Carrying structures are modeled, i.e. stack with R.C. annular plate at the chimney-top and corbels at the level of supporting slabs. All openings that influence the state of stress of the stack are included into the model. These are both openings in the chimney bottom for the main door and for the F.G.D inlet. Material properties are as follows; Concrete 32.0 MPa, E (Modulus of elasticity) = 28,000 MPa, μ (Poisson ratio) = 0.2, γ (Concrete density) = 25.0 kN/m^3.

4.2 Parametric study by changing chimney diameter

El-SUEZ concrete chimney on which the parametric study shall be performed is 152m height and 11.5m outside diameter with slenderness ratio 13.2. Normally and practically, the slenderness ratio varies between a range of 10 to 18. Four different diameters were chosen including the original one to examine the full applicable range. The following table shows the different diameters chosen and their corresponding slenderness ratio.

Modules	Height above ground (m)	Outside Diameter (m)	Slenderness Ratio
I	152	8.5	17.8
II	152	10	15.2
III (Original)	152	11.5	13.2
IV	152	15	10.3

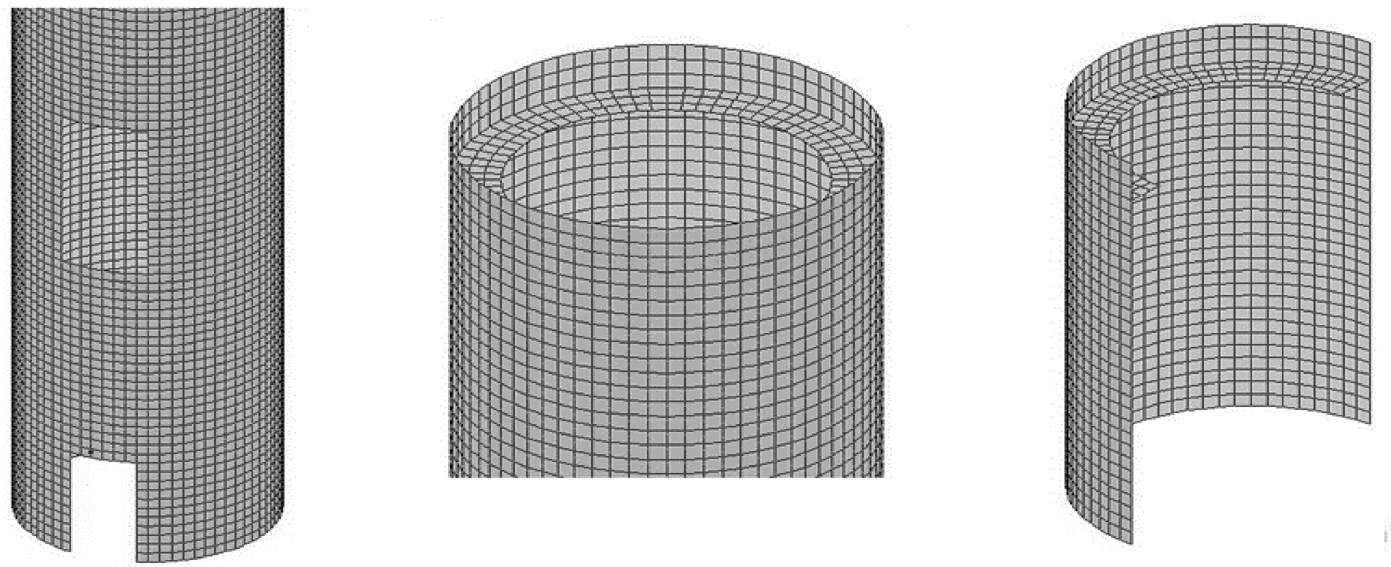

Fig. 4 Shell Model lower part with door and flue gas duct openings, upper part with top slab & vertical half-section in upper part

Table 4: Summary of Parametric study data & results by changing chimney diameter

SUEZ THERMAL POWER PLANT		Chimney Height 152.0m			
Parametric Study with fixed Height and Different Diameters	Unit	**Module I**	**Module II**	**Module III (original)**	**Module IV**
		Dimensions and Slenderness Ratio			
Bottom Outer DIA (D)	m	**8.5**	**10**	**11.5**	**15**
Total Height	m	153	153	153	153
Total Height above ground (H)	m	152	152	152	152
Slenderness Ratio - Height above ground/ Bottom Outer DIA (H/D)		17.88	15.20	13.22	10.13
Bottom Inner DIA (D)	m	7.6	9.1	10.6	14.1
Min. Shell Thickness according to ACI 307-08 [1] item 4.1.3	m	0.2	0.21	0.22	0.26
Flue duct opening height	m	8.05	8.05	8.05	8.05
Min. Shell Thickness according to opening height (Not less than 1/24 opening height) according to ACI 307-08 [1] item 4.1.3	m	0.34	0.34	0.34	0.34
		Ultimate Base Moments and Normal Forces			
Load Combination during Erection		0.9 D + 1.6 M along & 0.9 D + 1.4 M along+across			
Pu=0.9 D	kN	**28,700.13**	**33,972.41**	**39,244.69**	**51,546.67**
Mu along= 1.6 M along	kN-m	**207,658.44**	**237,158.78**	**266,281.87**	**333,030.49**
Mu combined= 1.4 M along+across	kN-m	N.A	N.A	N.A	**574,435.98**
		Ultimate Max Circumferential Bending			
Load Combination during operation		1.2 T + 1.4 M circumferential			
max Mu at Top = 1.4 M circumferential	kN-m/m'	18.59	26.04	34.69	59.78
max Mu at Bottom= 1.4 M circumferential	kN-m/m'	7.03	9.88	13.24	22.96

In order to judge the optimum thickness for a certain chimney height and diameter, three different shell thicknesses are assumed for each diameter chosen for the parametric study (0.35m, 0.40m and 0.45m) and if it is not safe, the thickness shall be increased by 5cm till safety is reached. Then, a check for deflection and local stresses around openings is performed to eliminate the unsafe thicknesses and to get the optimum shell thickness with its corresponding reinforcement. Wind deflection criteria in ACI 307-08 [1] clause "4.5" states that the maximum lateral deflection of the top of a chimney before the application of load factors shall not exceed the limits set forth by Eq. (2)

$$Y_{\max} = \frac{0.04h}{12} \qquad (2)$$

Where; Y_{max} maximum lateral deflection of top of chimney

h chimney height above ground level

The chimney fundamental period is first computed by the approximate ACI 307-08 [1] an equation for unlined shell, then it's extracted from the 3D finite element model for both lined and unlined shell. The following graphs and table will summarize the results for Ultimate Base wind Moment, fundamental periods, deflection and local stresses check and the optimum reinforcement for each shell thickness used for each module.

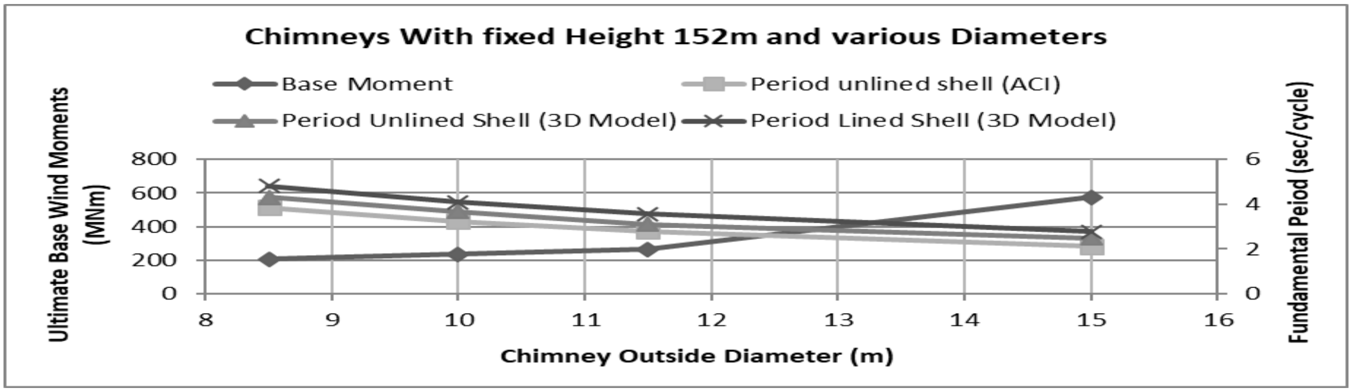

Fig. 5 Ultimate Base wind Moment and Fundamental Periods for chimneys with fixed height 152m and various diameters

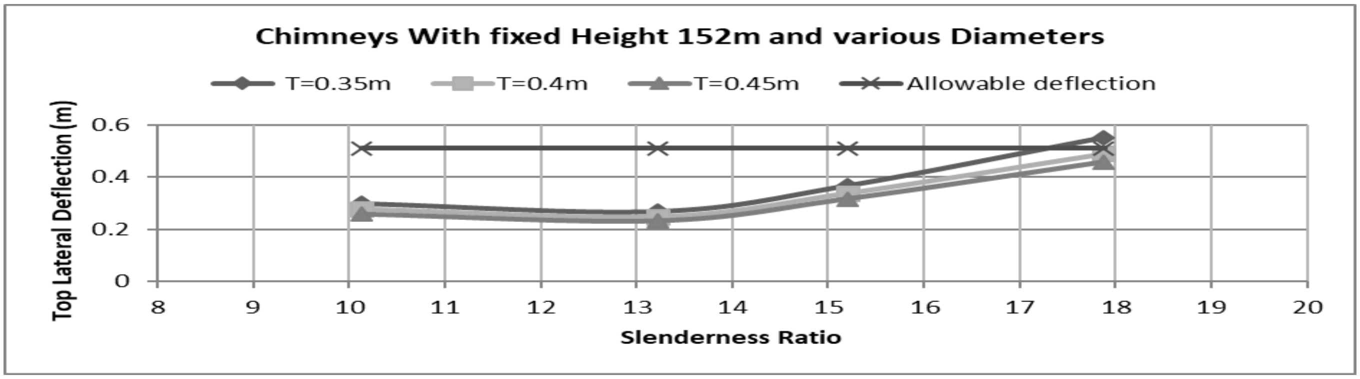

Fig. 6 Relation between Slenderness ratio & Deflection for various chimney diameters with fixed height 152.0m

Table 5 Summary of deflection, local stresses and reinforcement ratio for various chimney diameters

check for deflection & Section compressive strength	Unit	Chimney Height 152.0m Module I	Module II	Module III	Module IV
Bottom Outer DIA (D)	m	8.5	10	11.5	15
Bottom Shell Thickness (t)	mm	400*	400*	400*	400*
Flue duct opening Width (W)	mm	2760	3300	3600	5000
% VL RFT Lower Section (ρv)		1.03%	0.71%	0.50%	0.78%
Deflection at Top due to wind load	m	0.49	0.34	0.25	0.28
Max allowable deflection due to wind load	m	0.51	0.51	0.51	0.51
Safety with respect to Wind deflection		Safe	Safe	Safe	Safe
Local Compression Stress around openings	MPa	21.92	20.57	18.35	19.49
Concrete Compressive Strength	MPa	22.98	21.65	20.55	23.45
Check Local Stresses		Safe	Safe	Safe	Safe

*The chimney thickness 350mm was unsafe in deflection for Module I only, while it was unsafe for local stresses check around openings in all other Modules.

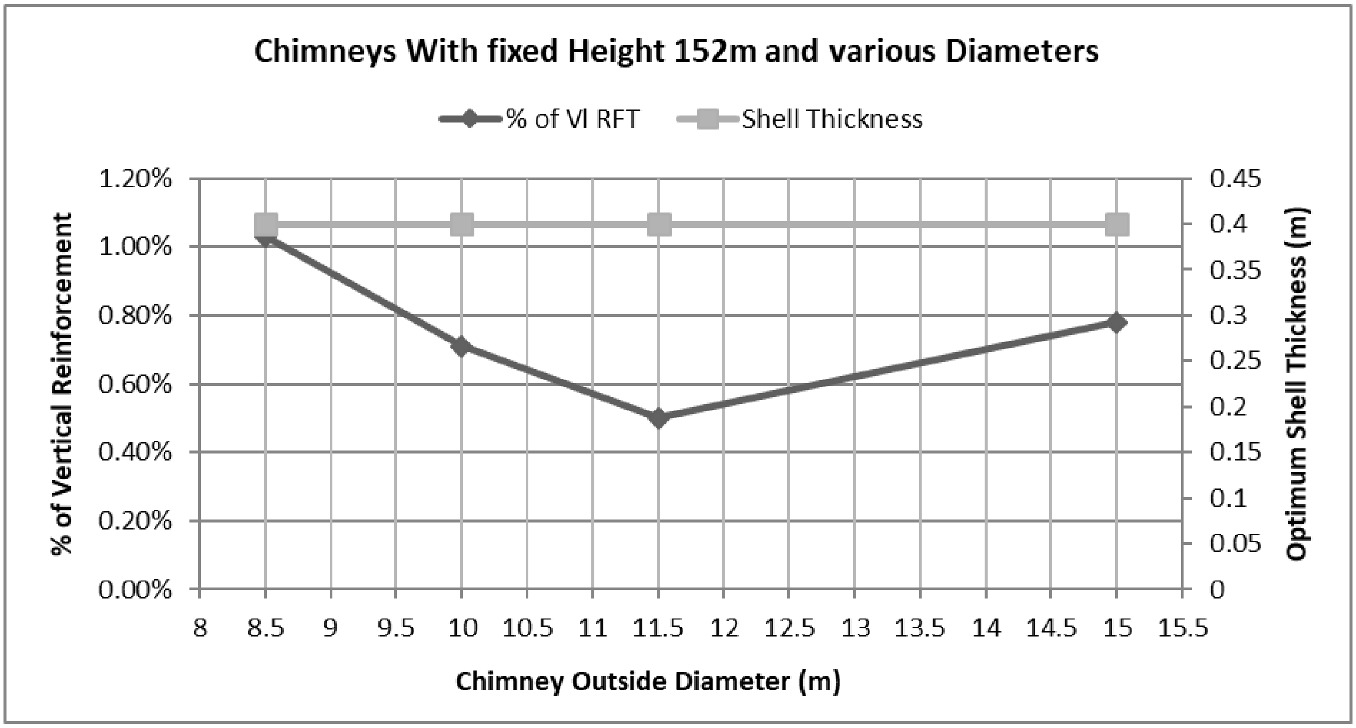

Fig. 7 Relation between Chimneys various Diameters & optimum Vertical RFT and Shell thicknesses for fixed chimney height 152m

4.3 Parametric study by changing chimney height

Four different heights were chosen including the original one to examine the full applicable range. The following table shows the different heights chosen and their corresponding slenderness ratio.

Table 6 Chimney Modules for different diameters

Modules	Height above ground (m)	Outside Diameter (m)	Slenderness Ratio
I	114	11.5	9.9
II (Original)	152	11.5	13.2
III	177	11.5	15.3
IV	203	11.5	17.6

Table 7 Summary of Parametric study by changing chimney height

SUEZ THERMAL POWER PLANT	Chimney Outer Diameter 11.50m				
Parametric Study with fixed Diameter and Different Heights	Unit	**Module I**	**Module II (original)**	**Module III**	**Module IV**
	Dimensions and Slenderness Ratio				
Bottom Outer DIA (D)	m	11.5	11.5	11.5	11.5
Total Height	m	**115**	**153**	**178**	**204**
Total Height above ground (H)	m	**114**	**152**	**177**	**203**
Slenderness Ratio - Height above ground/ Bottom Outer DIA (H/D)	0	9.91	13.22	15.39	17.65
Bottom Shell Thickness	m	0.45	0.45	0.45	0.45
Min. Shell Thickness according to ACI 307-08 [1] item 4.1.3	m	0.22	0.22	0.22	0.22
Flue duct opening height	m	8.05	8.05	8.05	8.05
Min. Shell Thickness according to opening height (Not less than 1/24 opening height) according to ACI 307-08 [1] item 4.1.3	m	0.34	0.34	0.34	0.34
	Ultimate Base Moments and Normal Forces				
Load Combination during Erection	0.9 D + 1.6 M along & 0.9 D + 1.4 M along+across				
Pu=0.9 D	kN	**30,160.14**	**39,244.69**	**45,301.05**	**51,357.41**
Mu along= 1.6 M along	kN-m	**139,557.15**	**266,281.87**	**378,946.46**	**513,630.59**
Mu combined= 1.4 M along+across	kN-m	**254,400.84**	N.A	N.A	N.A
	Ultimate Max Circumferential Bending				
Load Combination during operation	1.2 T + 1.4 M circumferential				
max Mu at Top = 1.4 M circumferential	kN-m/ m'	33.48	34.69	35.34	35.87
max Mu at Bottom= 1.4 M circumferential	kN-m/ m'	13.24	13.24	13.24	13.24

The same procedure used in the previous parametric study in item 4.1 shall be applied. The following graphs and table will summarize the results for Ultimate Base wind Moment, fundamental periods, deflection and local stresses check and the optimum reinforcement for each shell thickness used for each module.

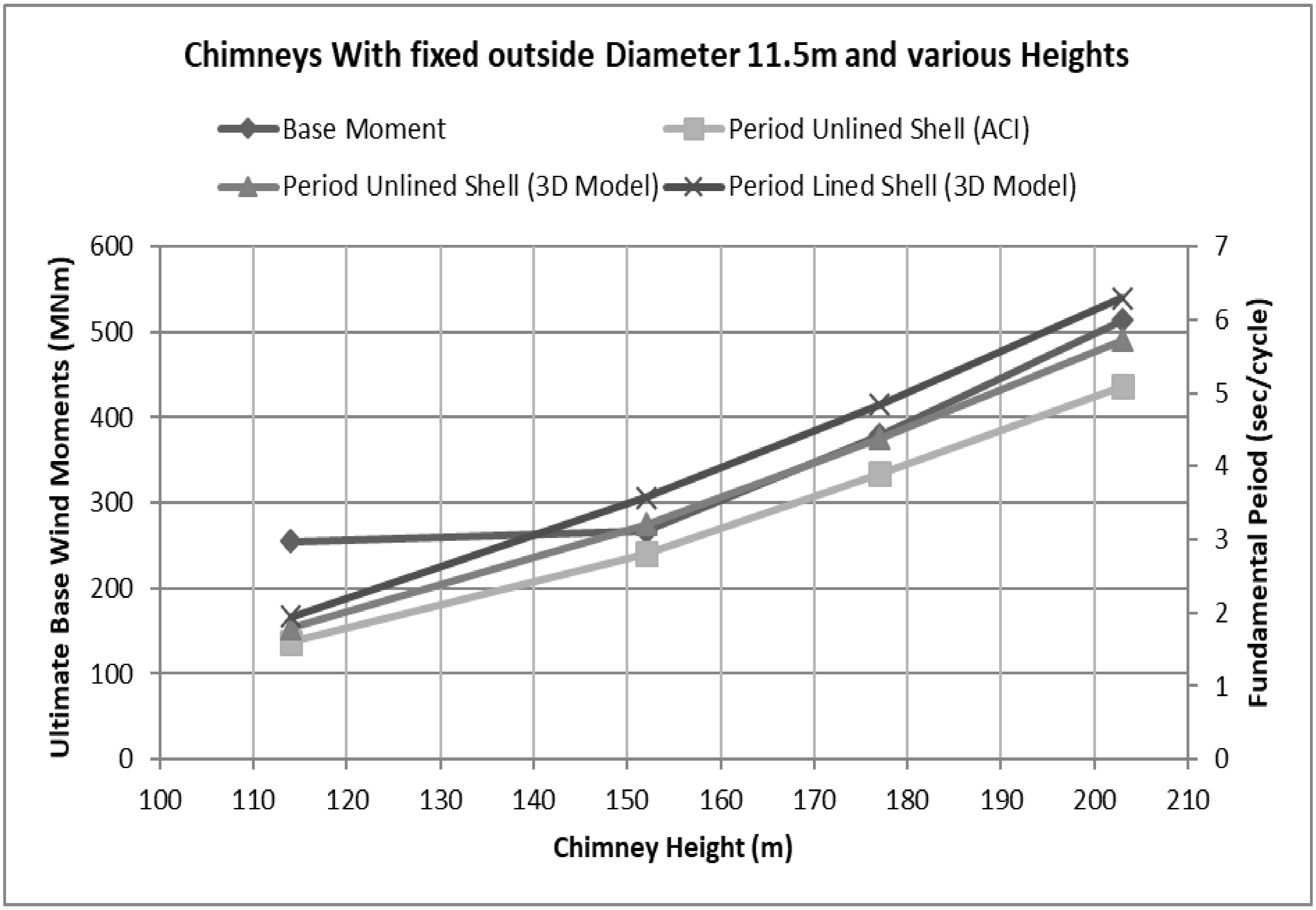

Fig. 8 Ultimate Base wind Moment and Fundamental Periods for chimneys with fixed diameter 11.5m and various heights

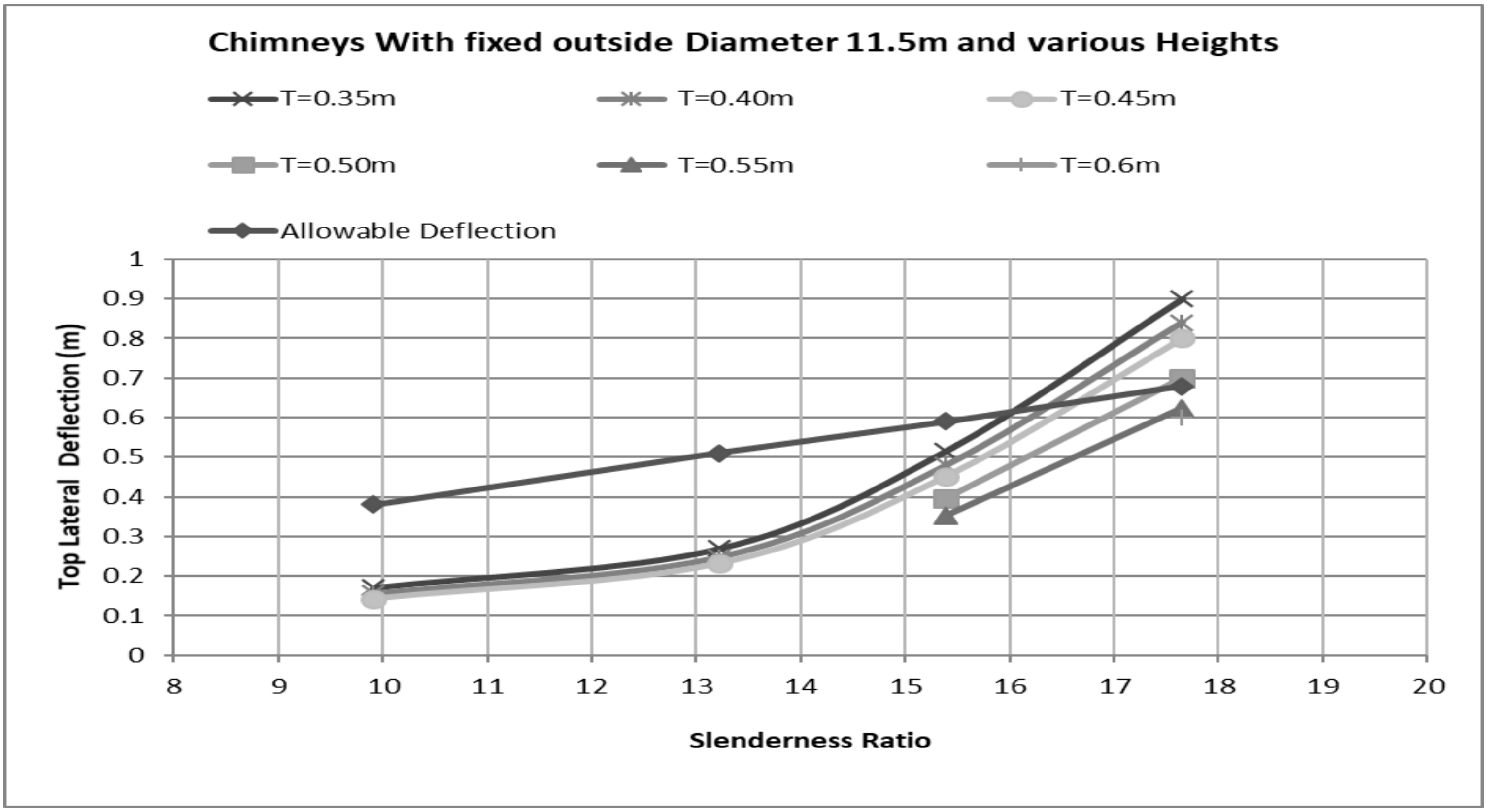

Fig. 9 Relation between Slenderness ratio & Deflection for various chimney heights with fixed outside diameter 11.50

Table 8 Summary of deflection, local stresses and reinforcement ratio for various chimney heights

check for deflection &		Chimney Outer Diameter 11.50m			
Section compressive strength	**Unit**	**Module I**	**Module II**	**Module III**	**Module IV**
Total Height above ground (H)	m	114	152	177	203
Bottom Shell Thickness (t)	mm	350*	400*	500*	600*
Flue duct opening Width (W)	mm	3600	3600	3600	3600
% VL RFT Lower Section (ρv)		0.66%	0.50%	0.70%	0.94%
Deflection at Top due to wind load	m	0.17	0.248	0.396	0.6
Max allowable deflection due to wind load	m	0.38	0.51	0.59	0.68
Safety with respect to Wind deflection		Safe	Safe	Safe	Safe
Local Compression Stress around openings	Mpa	19.51	18.35	20.84	21.68
Concrete Compressive Strength	Mpa	21.91	20.55	21.28	22.13
Check Local Stresses		Safe	Safe	Safe	Safe

*The chimney thicknesses 350,400, 450 & 500mm were unsafe in deflection for Module IV only. The increment of shell thicknesses in the above table is due to the local stresses check around openings

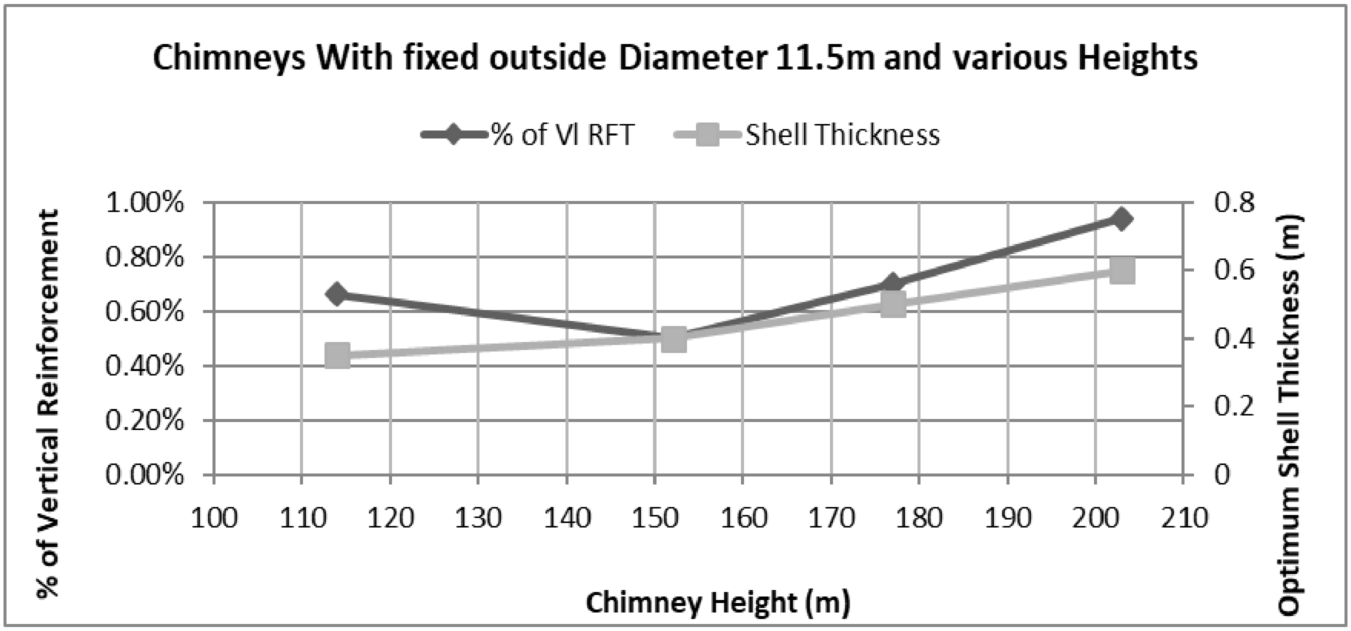

Fig. 10 Relation between Chimneys various Heights & optimum Vertical RFT and Shell thicknesses for fixed chimney diameter 11.5m

It's obvious that the key role of the optimum design of a certain chimney is the shell thickness. Whatever was the ratio of reinforcement used in the section (recommended 1% maximum for the ease of construction), the minimum thickness used is always the more economical design. Then, after determining the chimney height and diameter by the authority regulations and gas pressure calculation, the minimum shell thickness required by the code in ACI 307-08 [1] shall be computed. This minimum thickness shall be our first assumption and it shall be checked for deflection to satisfy the deflection criteria stated by the code and shall be checked for local stresses around the openings not to exceed the allowable compressive concrete strength. The following tables are concluded for the optimum shell thicknesses and reinforcement ratio for a certain chimney height and diameter by using the simplified method given by ACI 307-08 [1].

Table 9 Optimum shell thicknesses and % of RFT for chimnModules with fixed height 152.0m and different diameters

Modules	Height above ground (m)	Outside Diameter (m)	Slenderness Ratio	Optimum shell thickness (m)	Optimum Vl. RFT Ratio	Optimum Hz. RFT Ratio
I	152	8.5	17.8	0.4	1.03%	0.20%
II	152	10	15.2	0.4	0.71%	0.20%
III (Original)	152	11.5	13.2	0.4	0.50%	0.20%
IV	152	15	10.3	0.4	0.78%	0.20%

Table 10 Optimum shell thicknesses and % of RFT for chimney Modules with fixed diameters 11.5m and different heights

Modules	Height above ground (m)	Outside Diameter (m)	Slenderness Ratio	Optimum shell thickness (m)	Optimum Vl. RFT Ratio	Optimum Hz. RFT Ratio
I	114	11.5	9.9	0.35	0.66%	0.20%
II (Original)	152	11.5	13.2	0.4	0.50%	0.20%
III	177	11.5	15.3	0.5	0.70%	0.20%
IV	203	11.5	17.6	0.6	0.94%	0.20%

5. Conclusions

From the parametric study made either by changing chimney diameters for 152m chimney height or by changing chimney heights for 11.5m chimney outer diameter, the followings are concluded:

The slenderness ratio of 13.2 gave the lowest ratio of vertical reinforcement for all Modules with various thicknesses.

The slenderness ratio of 13.2 for Module II for various diameters gave the lowest top deflection for all various thicknesses. On the other hand, the slenderness ratio of 9.9 with the lowest height for Module I for various heights gave the lowest top deflection for all various thicknesses.

It's recommended to use a slenderness ratio not less than 13.0. Using less than this ratio either by decreasing chimney height or increasing chimney diameter will attract more vertical reinforcement for applying across wind load and more horizontal reinforcement due to large circumferential bending applied on large chimney diameters.

When slenderness ratio drops below 13, the effect of across wind attracts additional moment on chimney section and accordingly the increase of vertical reinforcement ratio may reach up to 300% from its original value.

A flowchart summarizing the chimney design process is shown in the next figure. Structural engineers can use this flowchart as a guide for concrete chimney design.

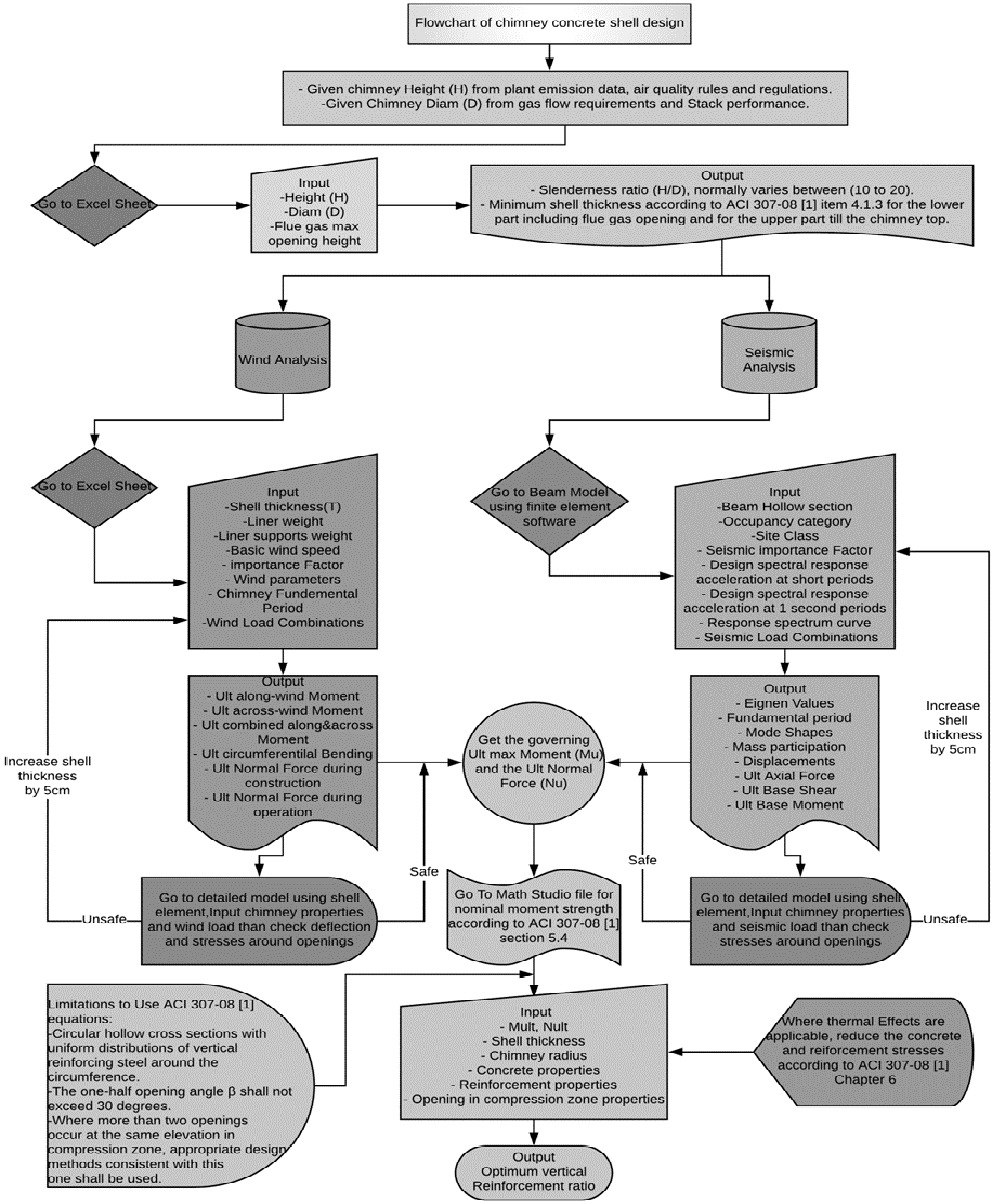

Fig. 11 Flowchart Summarizing the Chimney Shell Design Process

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SELECTION CRITERIA OF WASTEWATER TREATMENT TECHNOLOGIES

Article By : Moataz Khalif

1. INTRODUCTION

The technology to be selected in waste water treatment plants is varying and each treatment step has various technologies that can be applied. In general the treatment of waste water involve the following steps:

- **Pretreatment** : coarse screening and sand/grit removal
- **Primary treatment** : sedimentation of settable particles
- **Secondary treatment** : includes the biological treatment to reduce the BOD/COD
- **Disinfection** : adding of disinfectant chemical to maintain a residual for preventing growth of microorganisms
- **Tertiary treatment** : involves additional treatment to remove nutrients and/or more reduction of BOD/COD
- **Sludge treatment** : involves thickening and dewatering of sludge for easier disposal as well as digestion system for energy generation

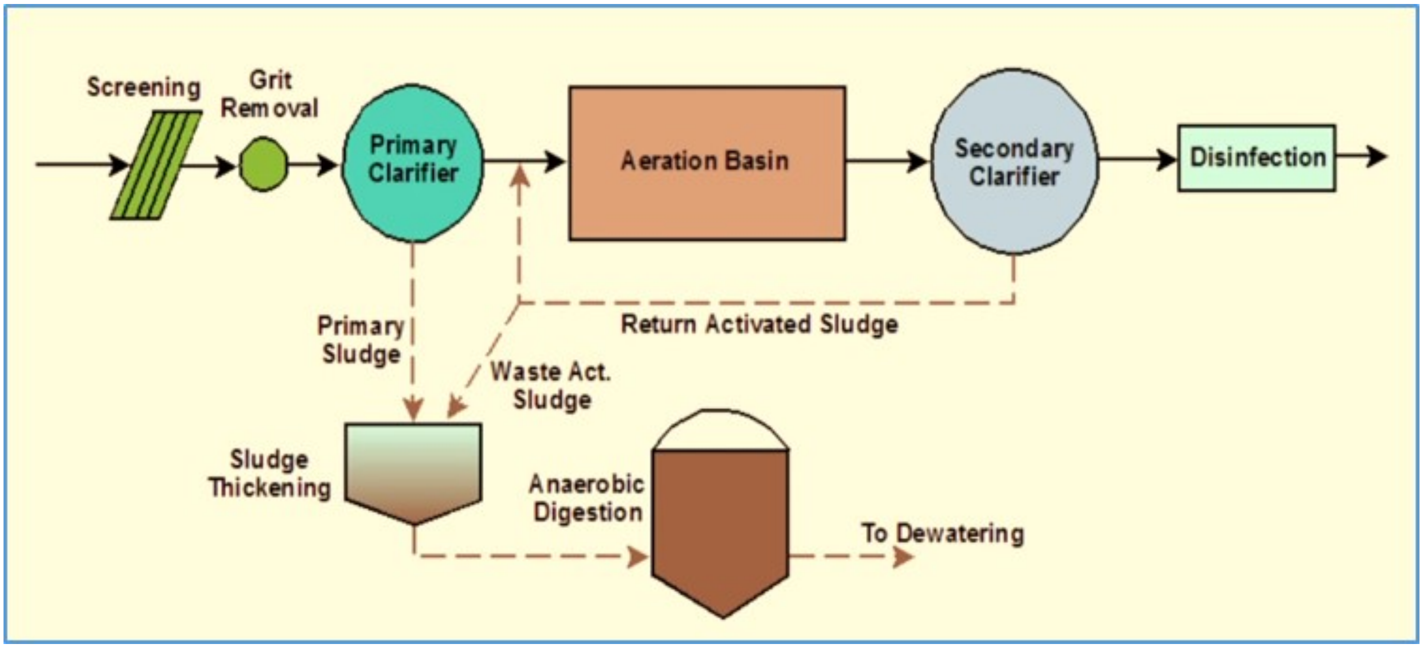

Fig. 1

2. Classification of Criteria for Selection of Wastewater Treatment Technology (levels of criteria)

Planning and implementation of wastewater treatment systems comprises many aspects not only the technical requirements but includes other non-technical aspects that are contributing on the technology selection. Aspects can be classified as follows:

- Administrative Aspects
- Environmental Aspects
- Technical Aspects
- Economic Aspects

Each class of the above-mentioned aspects includes multiple criteria that shall be evaluated in order to achieve the proper technologies to this specific aspect. After reaching a shortlist of technologies corresponding to each aspect another assessment is required to merge the evaluation of all classes of aspects in order to achieve the most proper set of technologies that normalize all criteria

3. List of criteria to be considered

Selection of the best wastewater treatment process is a multi-criteria decision making problem and there are various criteria for each category:

Administrative criteria

- Owner's requirements (preference)
- Type of the project delivery (IWP, EPC, DBO, BOOT etc....)
- Nature of the project (new, extension, rehabilitation)
- Schedule of the project
- Localization necessity
- The availability of local skills for design, construction and O&M.
- O&M requirements (special skills)
- Man power availability and requirements
- Stakeholder opinions

Environmental criteria

- Codes, standards, and regulations
- Effluent quality requirements (Environmental regulation)
- Impact on environment (emission of gases, solid waste)
- Environmental conditions such as land availability, geography and climate.

- The discharge standards for treated effluents.
- Noise requirements
- The future opportunities to minimize pollution loads.

Technical Criteria

- Plant capacity (influent flow rate and variability)
- Raw Water quality and variability
- Effluent quality requirements
- Sludge processing requirements (quantity, quality, disposal)
- Foot print availability and requirements
- The size of the community to be served
- Plant location and condition of surrounding
- Climate condition at plant location (Temp., humidity, wind etc...)
- Availability of operational material
- Evaluation of current technologies used in the region of the project
- O&M complexity and automation requirements
- Reuse applicability
- Constructability
- Reliability requirements (electro-mechanical)

Economic criteria

- Energy requirements (type and availability)
- Capex (investment)
- Opex (labor, energy, chemicals)
- Water production cost
- Sludge disposal cost
- Available Operation budget
- Nature of project fund (debt, loan, equity)
- Service fees collection and subsides

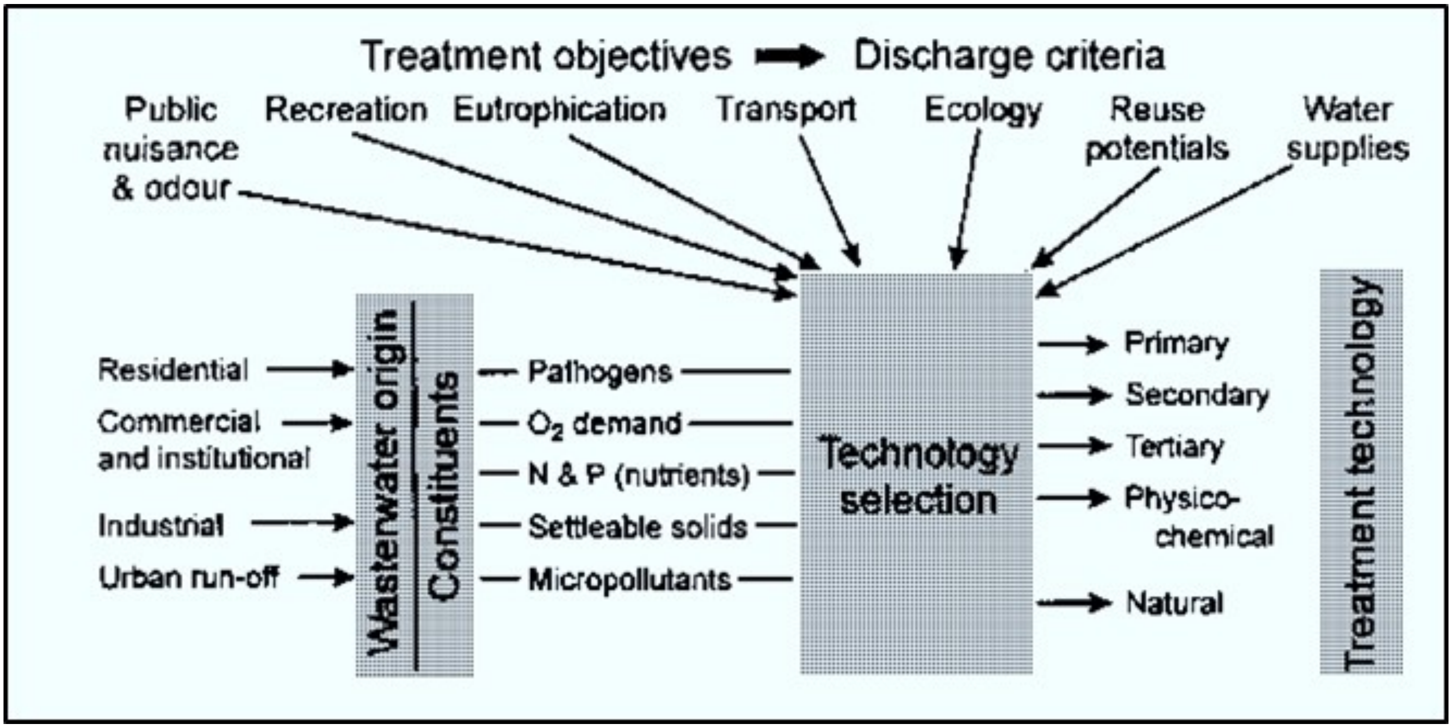

Fig. 2

4. Decision making (decision tree)

Decision shall be based on analysis of all criteria list above in same order, i.e. first evaluate and analyze the administrative criteria and make initial screening then evaluate and analyze the environmental criteria and make another screening and so on for technical and economical criteria. This hierarchy provides better evaluation because less technologies will be analyzed after each screening. The hierarchy may be changed based on changing priorities.

5. References

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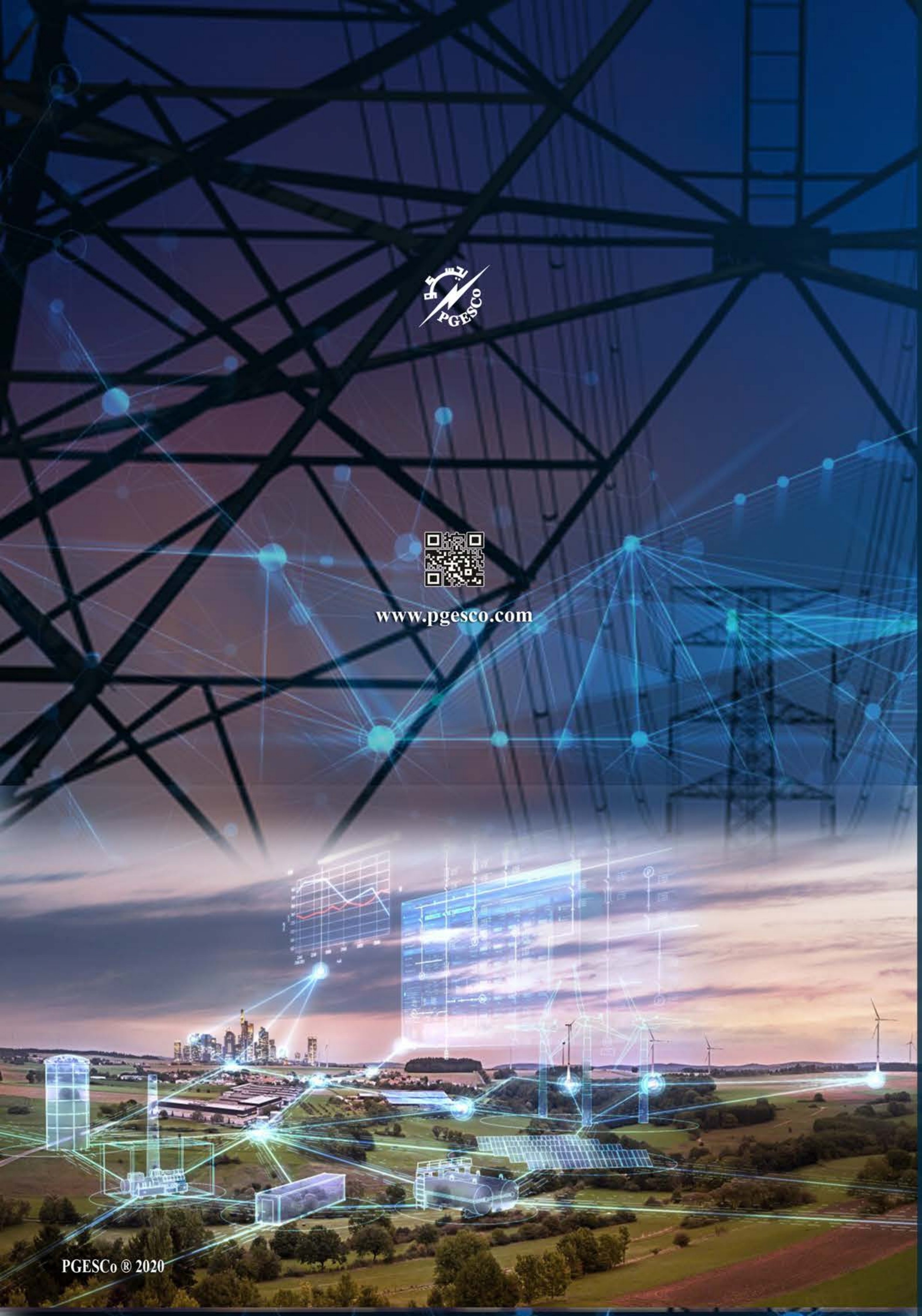

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