EVALUATING THE ENERGY SYSTEM IN YEMEN

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Abstract: *This paper presents a deep analysis for the energy system in Yemen, which consists of thermal power plants taking into account the strengths and weaknesses of its power system. The investigation results show that Yemen power system suffers lacking of energy efficiency (EE), weak institutional capacity, high losses in the generation, transmission and distribution grids, and currently the disability to invest in renewable energy (RE). Yemen should focus on foundational activities to build institutional capacity and mobilize resources to initiate suitable energy efficiency policies and measures. Yemen should also focus on exploring the opportunities of designing innovative energy systems based on decentralized small-scale power generation. Microgrids could enable power supply to remote areas at lower costs than required by traditional infrastructure.*

Key words: *energy efficiency, renewable energy, Yemen Power System, Al-Mukha wind farm.*

1. Energy Sector in Yemen.

The Yemeni energy sector consists of oil, natural gas, and biofuels. Energy production in 2012 was 15,109 kilotonne of oil equivalent (ktoe) while the consumption was 6,923 ktoe. Figure 1 shows the share of total primary energy supply in 2012 [1, 2]. In 2013, Yemen generated 5,600 GWh of electricity; 2,879 GWh from oil (steam and diesel power plants) and 2,722 GWh from gas, and consumed 4,976 GWh (consumption is currently not actually estimated because of the political situations) [3].

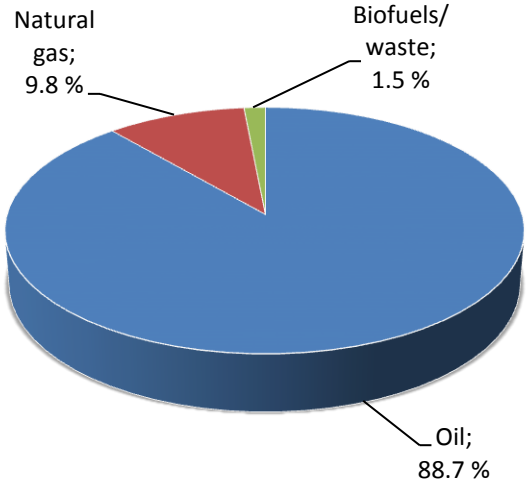

Fig. 1. Share of total primary energy supply in 2012 [2]

2. Ownership and Role of Government

The electricity sector in Yemen is fully managed by the Ministry of Electricity and Energy. The Public Electricity Company (PEC), which accounts for 80% of the generation capacity of the country, is 100% state-owned company. Supplying the rural areas is under the responsibility of the Public Authority of Rural Electrification. The main institution responsible for developing renewable energy policy is the General Department for RE of the Ministry of Electricity and Energy [4, 5].

3. Characteristics of Yemen Power System.

Electricity in Yemen mainly depends on oil power plants; 699 MW from diesel, 495 MW from steam, and 341 MW from gas power plants. The total capacity of the national grid in 2013 was 1,535 MW [3]. The power plants generate electrical power at different voltage levels which are 10.5 kV, 11 kV, 13.8 kV, and 15 kV and then the voltage levels are boosted to the transmission voltages levels of 230 kV and 400 kV. The medium voltage level of 33 kV is used to transmit the electricity from the substations to the demand locations. The distribution network uses the 11 kV to transmit the electricity to the distribution transformers. The nominal frequency for the grid is 50Hz. Figure 2 shows the single line diagram of Yemeni transmission grid with all power stations and substations [6].

Electricity tariff ranges from 4 Rial/kWh for urban households consumption to 30 Rial/kWh for government consumption. These prices are subsidized, which is a heavy burden for the deployment of RE technologies [7], so it is expected to be increased.

Yemen's population has the worst access to electricity in the region, with only 52% are supplied and electricity of 331 kWh/capita [3]. The main network of Yemen connects the urban areas and main cities. What remains is assessed to get electricity for few hours per day from other sources, typically a diesel generator, or the use of PEC-managed local mini-grids and of independent neighborhood mini-grids.

The connected consumers to the network also suffer interruptions of electricity, with frequent blackouts because of the old, inefficient infrastructure of generation, and transmission and distribution, technical failures, sabotage, and repeated shortages in fuel, especially diesel fuel, in power stations.

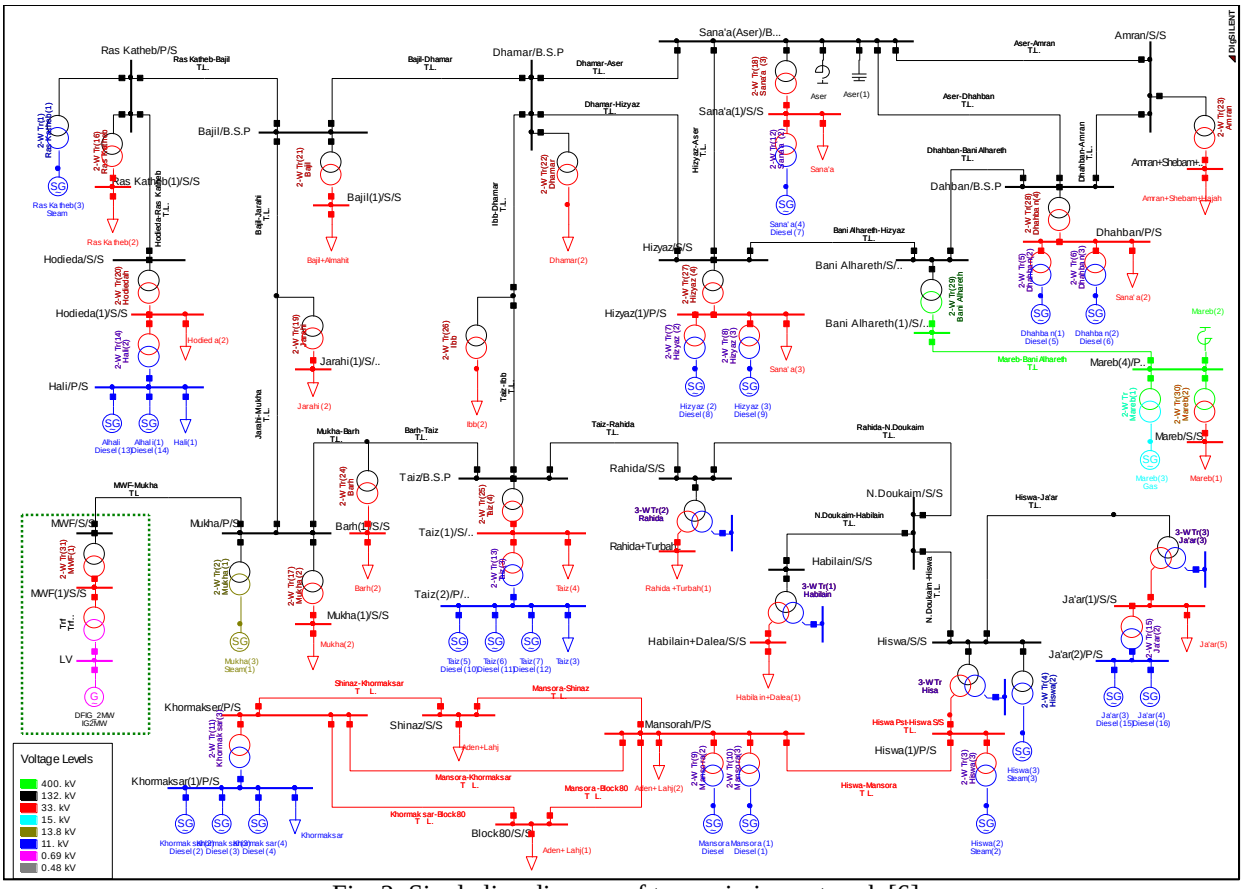

Fig. 2: Single line diagram of transmission network [6]

Yemen has a lagging grade in accordance with Arab Future Energy Index (AFEX) Energy Efficiency [8]. It lacks EE policies, has weak institutional capacity, and has high losses in the generation, transmission and distribution of power. However, Yemen has an average grade in accordance with AFEX Renewable Energy [9]. It faces the challenge of delivering electricity to the largest part of the population. Diesel is largely used to generate electricity and pump water. In 2014, the Government of Yemen (GOY) has largely increased diesel fuel prices, leading to tension and frustration in the community. Switching from diesel to solar energy can help enhancing people's lives. Due to the deteriorating political situation, Yemen is no longer able to progress in attracting investments in RE. Figure 3 and Figure 4 show the ranking of Yemen according to AFEX.

GOY is aggressively promoting RE and EE in the country. In 2009, GOY approved the national strategy for RE and EE, which aims to increase 15% of EE in the power sector by 2025. EE strategy includes providing 230 GWh/year through solar water heaters (SWH), 460 GWh/year by replacing economic lamps and electrification of 110,000 rural homes from the public network and 20,000 by solar photovoltaic (PV) off-grid installations [1, 10]. Multiple RE sources have been investigated in the strategy and action plan for RE. Figure 5 shows the targeted RE generation with share of 15% of electricity generation by 2025 [1, 10].

4. Renewable Energy in Yemen

People now know that oil is no longer reliable source of energy since it is not available because the situation is not stable, so the RE (solar energy in particular) is largely being considered by Yemenis. Figure 6 shows the solar and wind map of Yemen. Many people have resorted to PV as an emergency source for the household appliances. However, the overall size of the implementation of solar projects is only 3 MW in 2012 (0.075%) which is a small fraction [10]. For wind, GOY decided to build a wind farm with a target capacity of 60 MW at Al-Mukha in 2016 to demonstrate the financial viability of wind power.

In [11], the modeling and impact analysis of integrating Al-Mukha wind farm to the Yemen power system have been performed using the DIgSILENT program. The studies of load flow showed that the loading of most lines and voltage variations are slightly changed. Under the contingency situations, there is a thermal overload issue of the overhead lines. Additional findings from the transient stability studies indicate that this wind farm will not weaken the system transient stability.

The low-voltage ride-through study showed that after the fault is cleared, the wind turbine generators recovered their voltage level almost to its pre-fault voltage value. It is found that the proposed wind farm contributed voltage and current total harmonic distortions higher than the permissible limits specified in the standards. This would require a harmonic filter to be installed in order to mitigate the harmonics. As for the flicker, the resulting levels are far below any critical values so it can be assumed that flicker will not cause any problem in the studied case.

Table 1 shows the RE potential in Yemen [7] and Table 2 shows the strengths and weaknesses of RE.

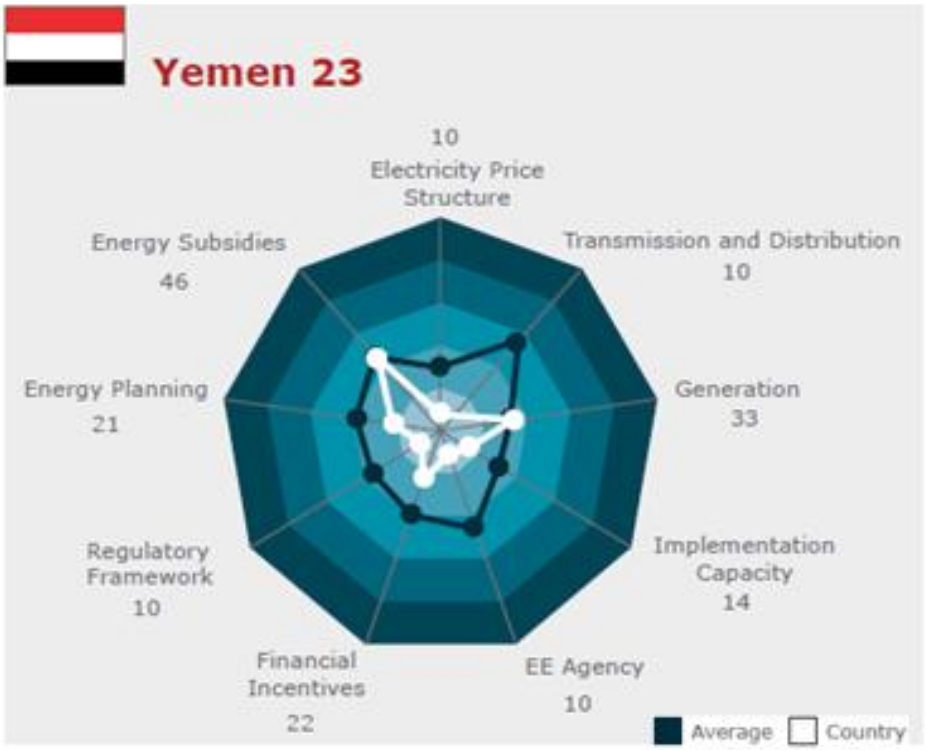

Fig. 3: Ranking of energy efficiency in Yemen [8]

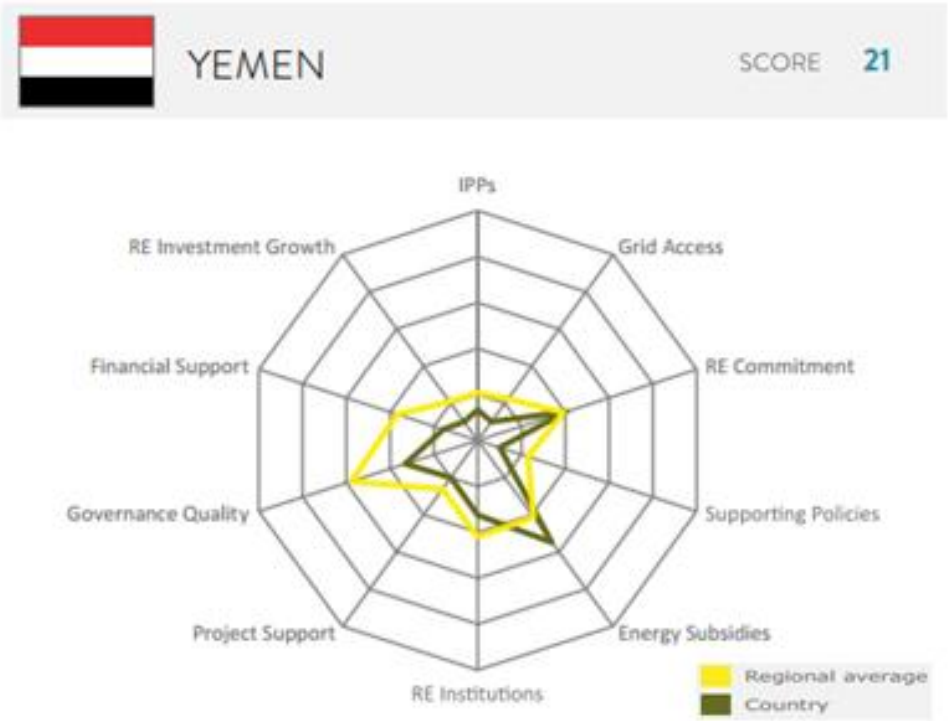

Fig. 4: Ranking of renewable energy in Yemen [9]

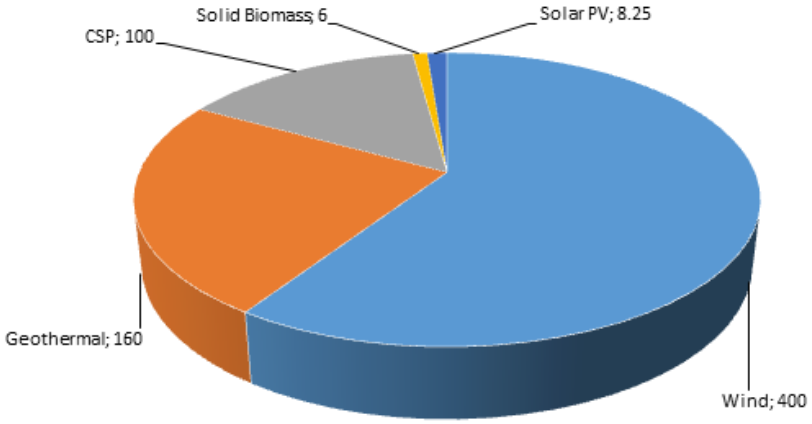

Fig. 5: Targeted capacity of RE in total electricity (in MW) by 2025 [10]

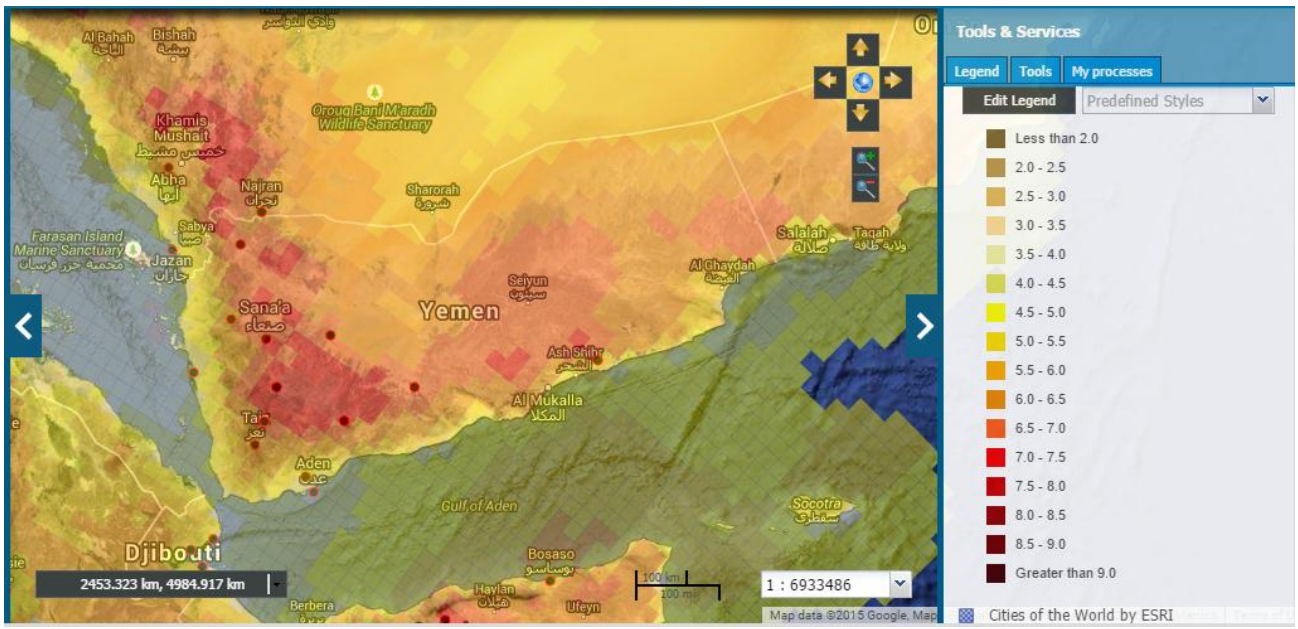

Fig. 6: Yemen map - solar and wind data [12]

Table 1
Grid-based renewable energy technical potential in Yemen [7]

Resource	Theoretical Potential (MW)	Technical Potential	
		Gross (MW)	Practicable (MW)
Solar electric (concentrated solar power)	2,446,000	1,426,000	18,600
Wind	308,722	123,429	34,286
Geothermal	304,000	29,000	2,900
Biomass (Landfill Gas)	10	8	6
Existing Dams	1	-	-
Major Wadis	12-31	11-30	-
Domestic (SWH)	3,014 $MW_{thermal}$	278 $MW_{thermal}$	278 $MW_{thermal}$

Table 2
Strengths and weaknesses of renewable energy

Resource	Strengths	Weaknesses
Solar	Renewable resource	Dependent on sunshine levels
	Clean source of energy	High capital costs
	Long lifetime	Requires storage system
Wind	Renewable resource	Competing land use
	Clean source of energy	Not reliable
	Sufficient level of maturity	Causes visual impact, noise, and electromagnetic interference
	Competitive in cost	Ecological impact
Geothermal	Stable	Requires complex management system
	Clean source of energy	Not sustainable
Biomass / Biofuels	Available and free resource	Competing land use
	Availability of conversion technologies	Requires complex management system

5. Conclusions and Recommendations

Deep analysis of the power system of Yemen has been performed. The paper showed that the current system is weak, and therefore the following recommendations are suggested:

- The country needs to focus on selecting priorities, energy planning and mobilizing efforts as it begins introducing EE measures.
- Switching from diesel to solar energy can help people improve their living conditions.
- Yemen should focus on exploring the opportunities for innovative energy systems design based on decentralized power generation.
- Microgrids could be able to supply power in remote areas at lower costs than traditional infrastructure required.

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