POWER FLOW MODELLING IN ELECTRIC NETWORKS WITH RENEWABLE ENERGY SOURCES IN LARGE AREAS

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Abstract
In many worlds regions there is a great potential for utilizing home grid connected renewable power generating systems, with capacities of MW thousands. The optimal utilization of these sources is connected with power flow possibilities trough the power network in which they have to be connected. There is necessary to respect the long distances among the electric power sources with great outputs and power consumption and non even distribution of the power sources as well. The article gives the solution possibilities for Libya region under utilization of wind renewable sources in north in shore regions.

Keywords
Wind power stations, Power flow in electric networks, Modelling of power flow

1 INTRODUCTION

Libya is an oil exporting country located in the middle of North Africa, with 6 million inhabitants distributed over an area of 1,750,000 km^2. The main part of country is located in the Sahara desert and northern part is situated on the Mediterranean Sea cost. All these areas have a great potential of solar and wind energy and the big percentage from that area is free. It makes from Libya a very good location for the purpose of renewable power sources. The daily average of the solar radiation on a horizontal plane in the coast region is 7.1 kWh/m^2 per day and in the southern region it is 8.1 kWh/m^2 per day. The daily average of the sun rising duration is more than 3500 hours per year. The coastal wind speeds in Libya in three sections of the coast with different levels of annual average wind speeds in 50 m above ground are from 4.7 to 9.1 m/s at the west coast, 5.4 to 8.9 m/s at the central coast, and from 5.6 to10.4 m/s at the east coast.

2 TRANSMISSION SYSTEM OF LIBYA

Unlike the rest of the African countries, where less than 10 % of population has an access to the electricity, Libya is a fully electrified country with current electricity consumption of 4360 kWh/p.c. with the good transmission and distribution electric system. The transmission system network is showed in Fig. 1. The Conference USB key will include all accepted papers uploaded before **February 17, 2012** if the registration fee for at least one author has been paid before **February 17, 2012**.

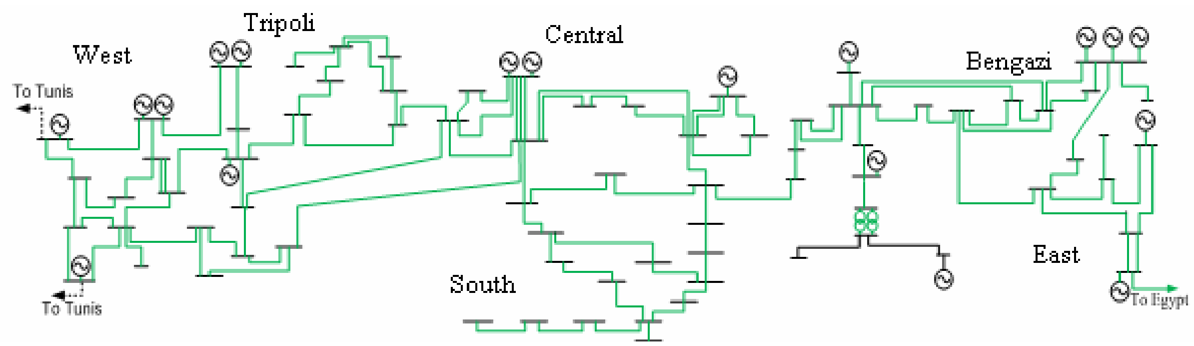

Fig. 1 Transmission power system of Libya

The transmission power system of Libya consists of six geographically dispersed, sparsely interconnected island areas (West, Tripoli, Central, Benghazi, Eastern and Southern regions), which consists of substations and lines on 400KV, 220 kV, and 132 kV levels with connections to sub-transmission networks of 66 kV and distribution systems of 30 kV and 11 kV. Connections in the transmission network of Libya are realized as overhead lines (14.747 km) and cables (138 km). For covering the power consumption, over 62 generating units are connected to the transmission network. These are mainly steam/gas-turbine and combined cycle power plants along with several smaller diesel generators located in rural areas of the Sahara Desert. The load in the last years was growing rapidly cause of changing the futures plane in the country and focus to the industries sectors and the agricultures as well (Fig. 2), which describes the load increasing the in the last years per years and per month as well.

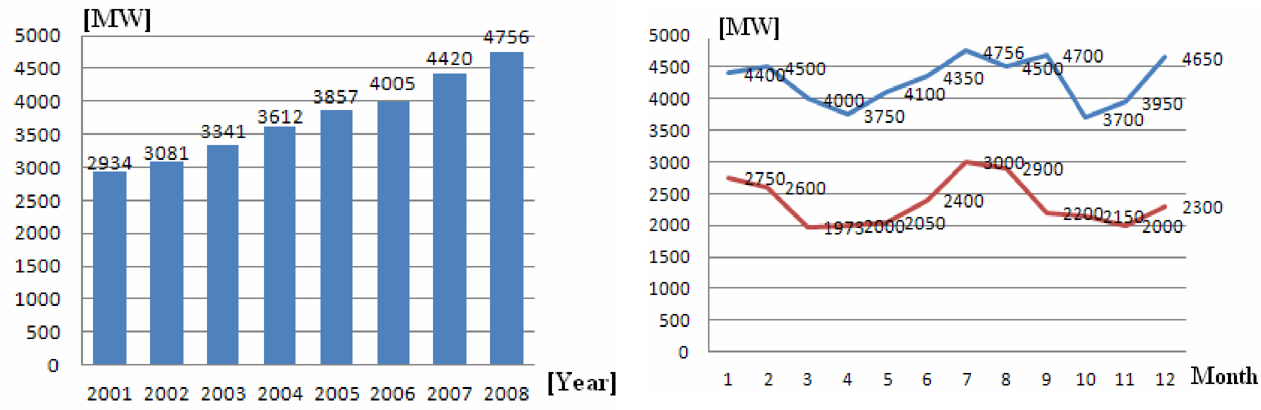

Fig. 2 Power load in transmission power system of Libya

Since being constructed in a broad time interval, huge variety of technological solutions performed by distinct power utilities and companies can be seen in the transmission network. This can be taken mostly as an advantage for the operation of the entire system, because this technological diversity prevent the occurrence of massive faults caused by possible hidden defect in the appliances provided by only one manufacturer. For the power consumption covering, over 62 generating units are connected to the transmission network of Libya. These are mainly steam/gas-turbine and combined cycle power plants along with several smaller diesel generators located in rural areas of the Sahara Desert. The present transmission operating value is visible in Fig. 3.

3 LOAD FLOW ANALYSIS OF THE TRANSMISSION POWER SYSTEM

Load flow analysis of the Libyan transmission network is relatively challenging due to several reasons:

1. The transmission network is only sparsely linked interconnecting individual consumption points at long distances (quite often over 200 kilometers).
2. The entire system is rather over-dimensioned, i.e. markedly lower loadings than transfer capacities of transmission lines/transformers can be found in the network leading to the Ferranti's phenomenon in some parts of the system. Therefore, large number of reactive power compensators (shunt inductors) is used almost at every substation to compensate capacitive currents in long lightly loaded circuits. Because of an insufficient capability for transmitting reactive power for long distances, however, bus voltage conditions can be strongly affected by these 'artificial loads'. Then, it is almost impossible to model the network without exact loading values in each bus of the system.
3. Approx. 61 % of total electric power is generated on the 220 kV level when compared to 30 % of power produced on the 400 kV level. Along with working interconnection to Egypt via a 220 kV circuit, it is more difficult to choose appropriate slack bus in the entire network for in-tended load flow calculations.
4. In total, this network contains two 400 kV, twenty two 220 kV and three 132 kV buses. From the 400 kV network, only Sirt and Benghazi North substations with fully operational gas power plant in the latter one have been included.

According to the result situation the modeling discussion about connecting of wind farms to the system was made with the inputting data and the necessary requirements for the operation states calculations:

- The 220 kV Benghazi North Power substation has been chosen as the slack bus for all simulations.
- Each PV bus in the network has been modeled with limited reactive power generations.
- Power injection from the 400 kV network to Sirt substation along with the intertie flows from Sirt to Zamzam in the west part from the local power network and from Tobruk to Salum, it is in the east part from a neighbor network from Egypt power network both injections have been included. Unfortunately, power flows in these circuits for a certain time interval were unknown.
- Active and reactive power values must be reasonably optimized for preserving full active power generation in the slack bus and voltage profiles within their permissible limits (±5 % in 400 kV, ±10 % otherwise).

- To preserve the maximum supply system independency on surrounding networks, the objective function minimizing the total area interchange has been used.
- The calculation value of power factor 0.9 for the maxi-mum active power (MW) of year 2010 has been used.
- The estimated power self-consumption (10 and 6 %) in each of considered three steam and six gas power plants, respectively were considered.
- Network topology with branches and shunt compensation data have been provided by the GECOL [3] annual report annual report data.
- For the optimization process, one particular non-commercial software package for optimization purposes – the NEOS Server [4] – has been used.
- For the verification of results obtained from the NEOS Server, professional programming tool Power World 13 GSO version [5] has been employed.

The load flow analyses of the network are shown in Fig. 3.

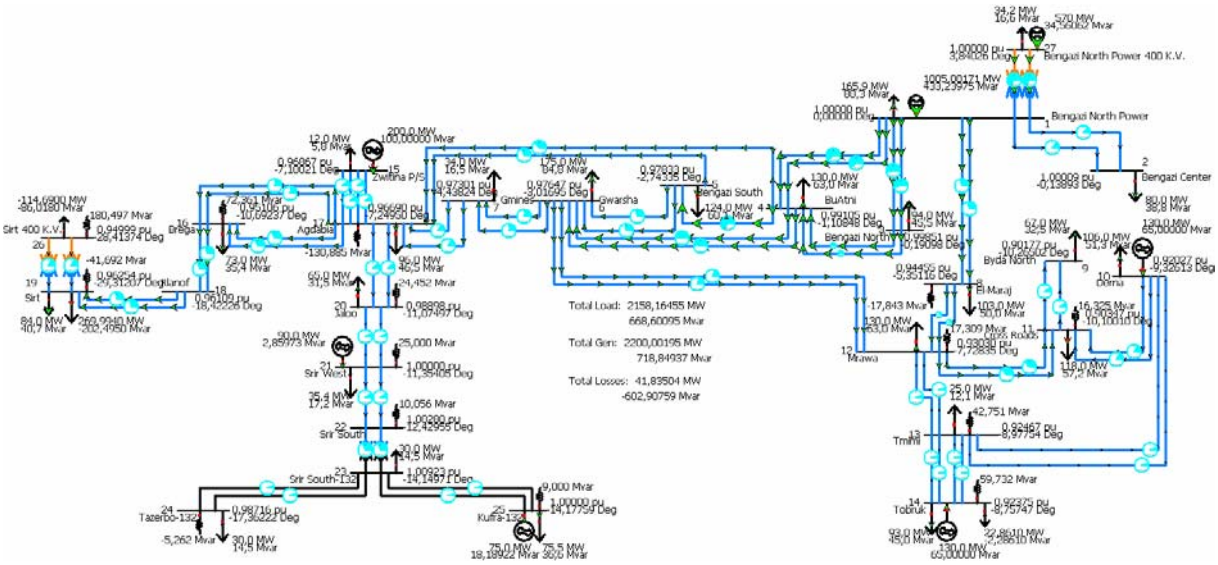

Fig. 3 Power flow load in transmission power system of Libya

All bus voltages are inside their permitted limits along with majority of branch loadings below 30 %. The maximum branch loading of 67.4 % was located on the overhead line between substations Bu Atni and Benghazi South.

4 SIMULATION OF NEW POWER CONCLUSION SOURCES

The measured data of wind energy showed the high potential of wind energy in Libya. There were to disposal the measured data of five coastal sites with 40 m measuring towers with anemometers in 10, 20 and 40 m above ground the location (Fig. 4).

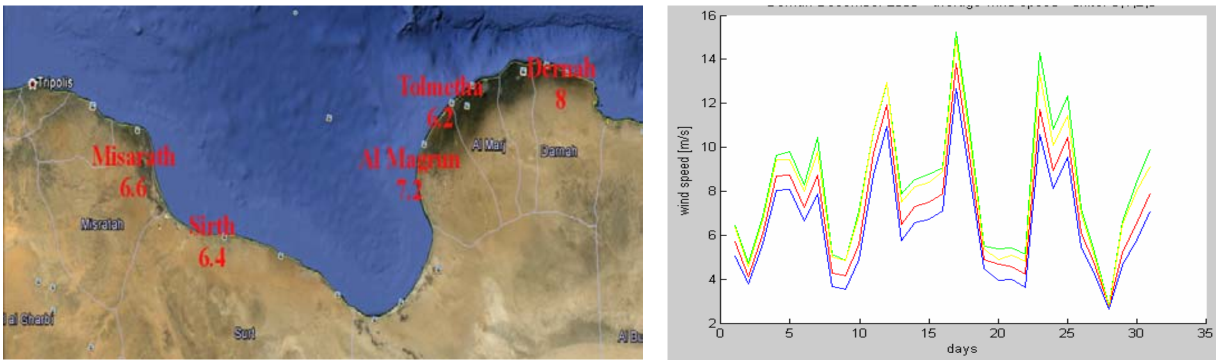

Fig.4 Wind speeds in northern part (Dernah) of Libya

These data were the inputting ones to calculate the power flow changes in the network. As the type of wind power generator inputting to the system (double fed induction generator) DFIG for the best efficiency system is used. The rotor side converter (RSC) can provides active and reactive power control of the machine while the grid-side converter (GSC) keeps the voltage of the DC-link constant. The example of used type of wind farm in Dernah has 9 MW capacity and it is consist of (6 of 1.5 MW each) wind turbines connected to 30 kV distribution system exports power to a 220 kV grid through a 30 km, 30 kV feeder as a maximum length. A 2300 V, 2 MVA plant consisting of a motor load (1.68 MW induction motor at 0.93 PF) and of a 200 kW resistive load is connected on the same feeder at bus B25 (Fig. 5).

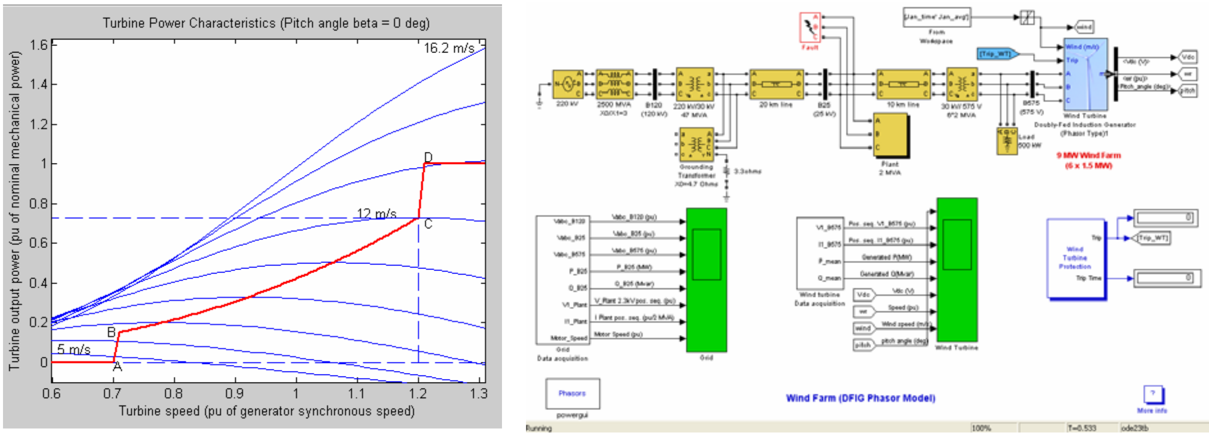

Fig. 5 Wind farm connected to the grid model

Both the wind turbine and the motor load have a protection system monitoring voltage, current and machine speed. The DFIG is controlled in order to follow the performance red curve.

There were calculated power flows after the planned wind power plants inputting to the system and compared with the theoretical possibilities. The Power World solution verifying the results from the NEOS Server is shown in Tab. 1.

Tab.1 Planned and theoretical wind farms

Wind power farm	Planned [MW]	Theoretical [MW]
Dernah	120	1794
Al-Maqrun	240	1681
Sirt	N/A	638
Tazerbo	120	100

5 CONCLUSION

The results of power flow analyses proved that the theoretical capacities of transmission grid are more than enormous for each proposed wind farm location. However, the theoretical limit for Tazerbo location is less than the planned generation.

Understandably, more practical limits should be evaluated using the transient power system analysis since it will more simulate the dynamics of the wind power generation and related network responds to these impacts. Nevertheless, the steady-state analysis clearly specifies the ceiling of the electricity generation because the limits obtained from the transient analysis will be always lower.

Similarly as in another countries lying in subtropical or tropical regions, electric power consumption in Libya is significantly higher in summer months than during the winter. This is good for the electric transmission possibility to north direction.

Anyway Dernah is the best place for wind farm inputting. The wind speed for this area makes it ideal to be the first farm and the other cities should follow on. The worked out calculation show that the network could easily accept new power sources connections. These sources could be wind farms or any another renewable power source of even from neighbour’s power networks.

6 ACKNOWLEDGEMENTS

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