December, January and February are 5.39 m/s, 7.27 m/s, 7.35 m/s and 6.26 m/s respectively. The extreme wind gust speed in the marine area of Kuwait is in the range of 25.5 m/s. In addition, Kuwait has an abundance of solar energy potential. Thereby, the monthly averaged solar intensity on horizontal surface area is 3.26 kWh/m^2 in December and 8.16 kWh/m^2 in June. The annual average value of solar radiation reaches 5.9 kWh/m^2. Moreover, the maximum incident solar radiation matches the peak load in summer.

Generally, tidal currents correlate well with the tidal range and then the tidal current speed can be described by an approximately linear function of the range. For example, on 22th of July of 2017, the sun rose in Kuwai**t** at 5:03 h and sunset was at 18:47 h. The first low tide was at 3:35 h and the next low tide at 17:20 h. The first high tide was at 10:10 h and the next high tide will be at 23:45 h. The recorded height of maximum and minimum tide was 4.1 m and -0.3 m, respectively.

The studied SG consists of 5x900 kW offshore floating wind turbines and 5x1 MW tidal turbines with 22 kV inter-turbine and shore connection submarine cables of Al conductors and embedded optical fibers. The third renewable source is 4 MW PV panels and connected to the grid through smart DC/DC converter and DC/AC, 3-phase two-level inverter. After inversion the arrays are interfaced to the common PCC through 6 kV/22 kV transformer. The whole generation system is connected to the grid at PCC through 20 MVA and 22/132 kV substation.

Due lack of space, the energy supplied by the different renewable resources was calculated for time horizon of 24 hours. The hybrid energy resources of the studied smart grid consists of offshore wind farm, PV array and tidal energy conversion plant with capacity of 4.5, 4 and 5 MW, respectively. These capacities are estimated by generation expansion technique which is outside the scope of this paper. Two types of loads are considered, namely domestic static and small industrial dynamic load of 10 MW and 900 kW, respectively. For this study, the loads and weather data are forwarded to the Simulik model of the smart grid as lookup tables. The simulation of V2G behavior of considered 100 cars with 40 kW each is carried out for the same time scale of 24 hours. The depth of discharge (DOD) of the EV batteries should be equal or greater than 20%.

In this paper, the following three different car-user profiles are considered:

- Possible charge of 40% of EVs from charge station at work.
- No possible charge of 30% of EVs at work
- The rest of EVs with 30% are in charging/ discharging operation mode and can participate in frequency regulation of the grid.

The validity of the developed models is demonstrated using the described models in section 2 to extract the maximum power from different renewable resources. The charging/ discharging characteristics of EVs batteries is considered to reduce its fluctuations under abnormal conditions and load variations.

Fig. (3) shows the load curve of the studied smart grid. The peak load occurs at 16:00 with a value of 10 MW, The minimum load is at mid-night with 5.8 MW. The maximum and minimum reactive power are 3.3 MVAR and 1.7 MVAR, respectively. To study the behavior of the system under abnormal condition a 3-phase short circuit is simulated at 8:00 for a period of 100 sec. The generated power from PV array can be seen in Fig. (4). As indicated the generated PV power follows the daily variation in the solar radiation and the available solar power has been extracted. The participation of the PV array in supplying the grid load occurs during the period from 6:00 to 17:00. From this figure, it can be observed that the generated power from PV array is decreased to 60 % at 15:00 due to sudden shading for 5 minutes.

In Fig. (5), variation of the power generated by the offshore wind farm is displayed and this power is high when the wind speed is higher than the cut-in speed of 4 m/s. It should be noted that the generated power from the wind farm reaches its maximum value of 4.5 MW for the interval between 21:00 and 22:00, where the wind speed is greater than the rated value of 15 m/s and less than the cut-off speed of 25 m/s. Similarly, Fig. (6) displays the generated power from the tidal plant. The maximum tidal power of 5 MW occurs at 10:00, while the generated power is very small during the period between 16:00 and 19:00 where the tide stream velocity is ranging between 0.48 and 0.74 m/s.

As indicated in the simulation results, the generated power follows the variation of the weather parameters and tracks the maximum power available in the different renewable resources. Furthermore, Fig. (7) shows the daily variation of the state of charge of the plugged-in EV batteries participating in frequency regulation. The SOC starts from a value slightly above 0.9 and decreases during its discharge mode from midnight to 8:00 and charged again during the period of excess renewable generation from 8:00 to 15:00. After that, the SOC is decreased again during night where the PV solar energy is zero and the tidal energy is small.

The charging cycle of the EV profiles is displayed in Fig. (8). The charging intervals and duration depends on the amount of required load and the available renewable generations. Fig. (9) shows the grid frequency obtained by applying V2G concept. The grid frequency at 8:00 deviates from 50Hz (1 pu) due to the short circuit on load bus. The second frequency deviation occurs at 15:00 due to sudden decrease in generated PV power by shading effect. The initial controller parameters Kp, Ki and Kd are 3, 2 and 1, respectively. The final on-line tuned paramerers by minimizing ITAE are 1.49, 0.92 and 0.52, respectively. The simulation results indicate that the proposed on-line tuned controller reduces grid frequency fluctuations.

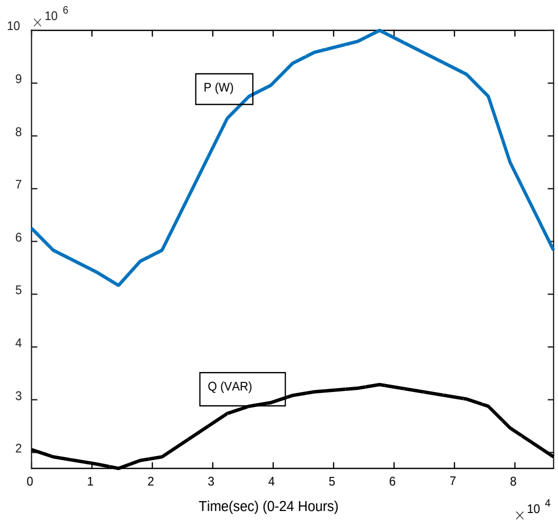

Fig. (3) Active and reactive daily load curve

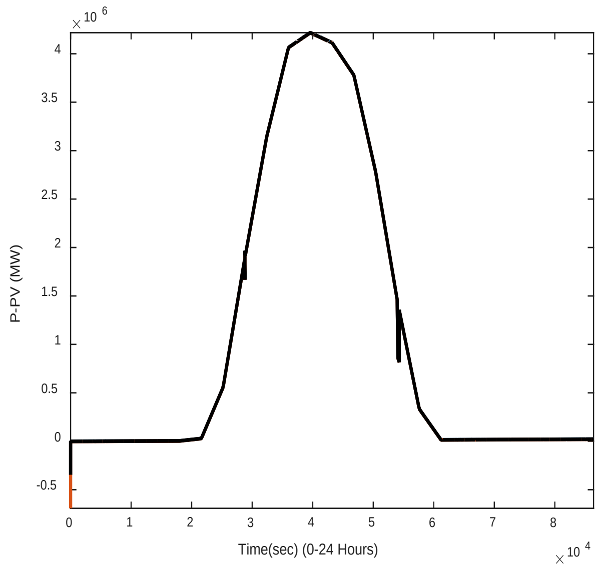

Fig. (4) Generated power from PV array

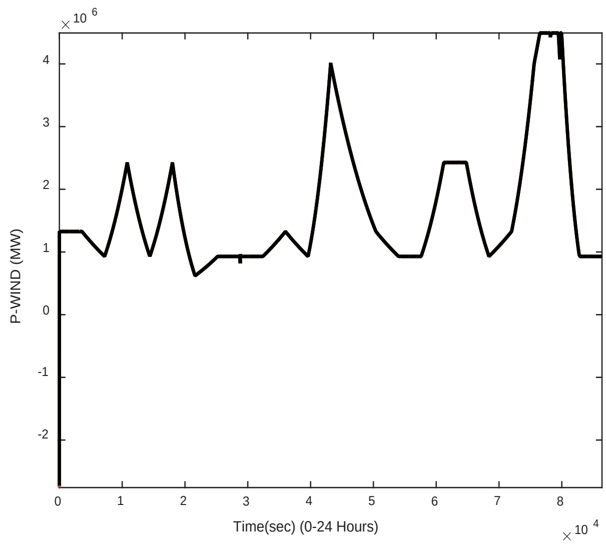

Fig. (5) Generated power from offshore wind farm

5. Conclusions and future research

For efficient utilization of hybrid renewable resources, it is necessary to install smart converters to extract the maximum power of these resources. Matlab/ simulink models have been developed for offshore wind, solar and tide plants. The generated power from these resources was simulated using the actual recorded weather data in Kuwait. The simulation results indicated that the generated energy was tracking the maximum available power of the renewable resources.

In addition, this paper has presented the interaction of electric vehicles with the smart grid containing renewable energy sources. This interaction can provide ancillary services to the grid through frequency regulation by deployment of the described V2G concept. This can be achieved utilizing advanced communication and on-line control strategies of smart grids.

The on-line parameters tuning algorithm of the PID controller has been developed to regulate the grid frequency. This parameter tuning has been achieved by minimizing the integral of time weighted absolute error in grid frequency based on smart grid facilities. The digital simulation of the studied grid has indicated that ITAE tuning method is very effective for eliminating the frequency error and reducing its oscillations during grid disturbances. However, cost-benefit analysis is required to justify future implementation of the V2G in energy market. Moreover, further studies are needed to develop EV batteries with high energy density and extended lifetime under frequent charging and discharging cycles.

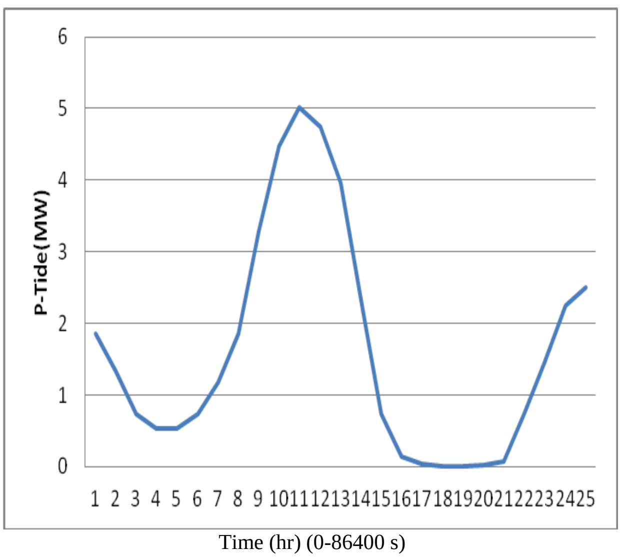

Fig (6) Generated power from tide plant

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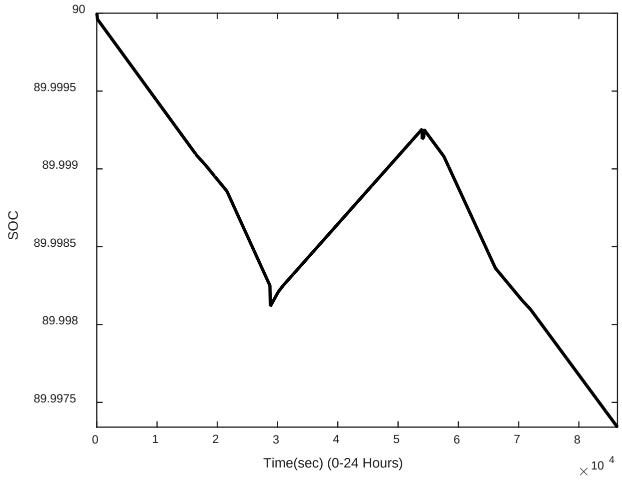

Fig. (7) Variation of Daily state of Charge

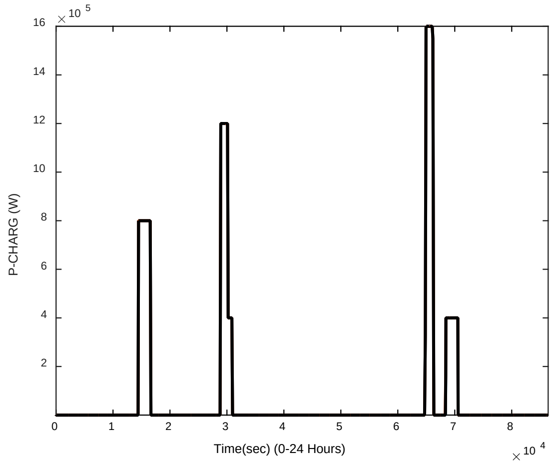

Fig. (8) Charging power of EV-batteries

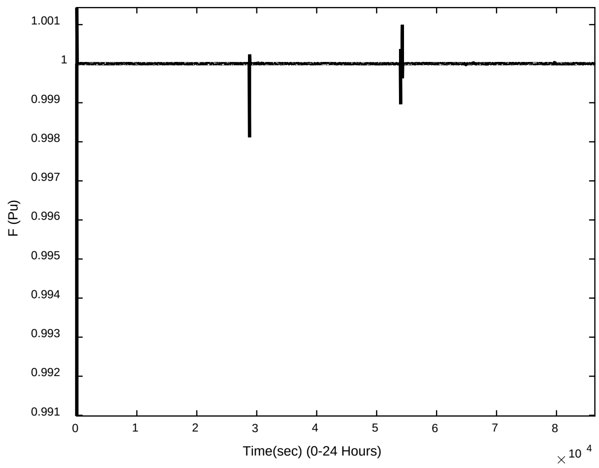

Fig. (9) Frequency variation under load and generation excursion.