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Article

Comparative analysis of power consumption time series in deprived and developed regions of Iran

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ABSTRACT

This paper presents a comparative analysis of power consumption time series at 12 o'clock every day between 2020 and 2022 for one distribution network in Sistan and one in Tehran. The aim of this study is to compare the development and climate differences between these regions, as well as the impact of social, industrial, and environmental factors. By comparing a deprived area with an area in the capital, we aim to identify potential disparities in power consumption and identify potential areas for improvement. We employed the CRP tool software and toolkit for time series analysis and used various methods to compare and predict the predictability of each time series. Our findings suggest significant differences in power consumption between the two regions, which could be attributed to socio-economic and environmental factors. Overall, this study sheds light on the potential impact of regional differences on power consumption and highlights the need for further research in this area.

1. Introduction

Time series analysis is a statistical technique that involves analyzing and modeling patterns in time-varying data [1,2]. It is used in many fields, including economics, finance, engineering, and the natural sciences [3-4]. One of the main goals of time series analysis is to understand the underlying processes that generate the data, which can then be used to make forecasts and predictions about future values [5]. For example, consider a company that wants to forecast its monthly sales for the next year. By analyzing historical sales data, they can identify trends and seasonal patterns, such as increased sales during the holiday season. Using time series analysis techniques, they can build models that capture these patterns and use them to make accurate predictions about future sales. Overall, time series analysis is a powerful tool for understanding and predicting patterns in time-varying data. By using appropriate techniques and models, analysts can make accurate forecasts and gain insights into the underlying processes that generate the data [6-10]. In this study, we compare and analyze two-time series related to power consumption at 12 o'clock every day in the period of 2012 to 2014 for two distribution networks in Sistan and one in Tehran. The goal of our analysis is to explore the differences in power consumption patterns between these two regions and to investigate the impact of various factors such as climate, industrial activity, and socio-economic conditions on power consumption. To prepare the data for analysis, we first normalized the time series to ensure that they conform to the assumptions of the time series model. We also de-trended the data to remove the effects of long-term trends and focus on the underlying patterns in the time series. Our analysis reveals interesting differences between the power consumption patterns in Sistan and Tehran. For example, we observe that the upward trend in power consumption is more pronounced in Tehran, possibly due to the faster rate of industrial development and population growth in the region. We also find that the impact of weather conditions on power consumption is more significant in Sistan, where most of the power consumption is due to household appliances (Figure 1 and Figure 2). Overall, our study sheds light on the complex interplay of various factors that influence power consumption patterns in different regions of Iran. The insights gained from this study can inform policy and decision-making related to energy consumption and sustainable development in the country.

2. Histogram Diagram

A comparison of the histogram diagrams in Figures 3(a) and 3(b) reveals that the power consumption in the Sistan network is higher than that of the region of Tehran under consideration. However, when the de-trended data in Figure 3(c) is compared, it becomes apparent that the load fluctuations are minimal throughout the year. This aspect is highly favorable for the operation of the system, and it makes the manufacturing sector more inclined to invest in such networks.

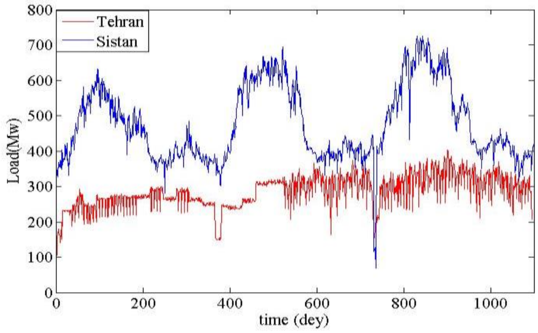


Figure 1. Load of Sistan and Tehran

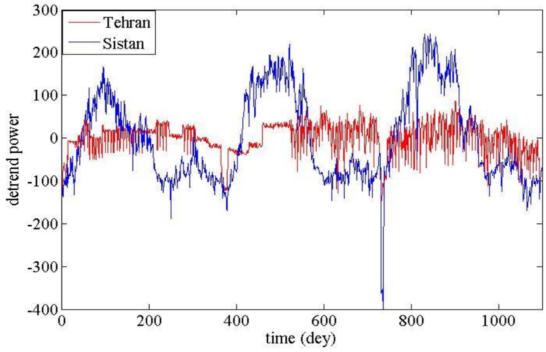


Figure 2. Graph related to the de-trended time series of Sistan power consumption and Tehran power consumption

3. False Nearest Neighbor

Figure 4 displays the False Nearest Neighbor (FNN) plot for both time series. This plot is generated using the FNN (data) command in MATLAB software and is commonly used to estimate the optimal embedding dimension for a time series. The FNN plot reveals that the Sistan time series has a dimension of 8, while the Tehran time series has a dimension of 7. This suggests that the Sistan time series exhibits less predictability and is more challenging to forecast accurately.

4. Mutual Information (MI)

Figure 5 displays the result of applying the mi (data) command, which utilizes the mutual information method to estimate the delay in the time series. The delay is found to be 6 for Sistan and 5 for Tehran, as determined by identifying the first minimum of the chart. Additionally, the False Nearest Neighbor (FNN) graph in Figure 4 shows that the Sistan time series has a dimension of 8 while the Tehran time series has a dimension of 7. These findings indicate that the Sistan network is less predictable and more difficult to forecast than the Tehran network. The fuzzy body diagram demonstrates that the behavior of both time series is chaotic, which suggests that they have limited predictability.

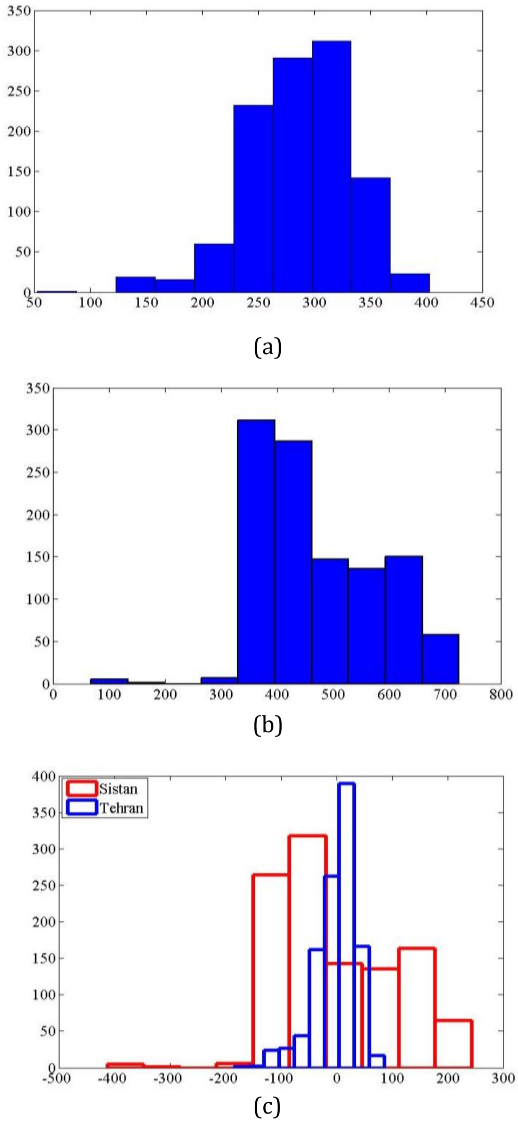


Figure 3. hist diagram: (a) Tehran (b) Sistan (c) detrend Tehran and Sistan

5. Cross Recurrent Plot

Figure 6 illustrates the cross-recurrence plot for both power consumption time series, revealing the chaotic nature of both systems. However, the plot for the Tehran network shows a higher number of parallel lines. As confirmed by previous methods, this indicates that the Tehran time series is more predictable than the Sistan time series. Notably, the large squares in the plot for the Sistan time series reveal its seasonal behavior, which was previously observed in the time series diagram.

6. xcf diagram

Figure 7 displays the cross-correlation function (xcf) diagram for both time series. The xcf command is used to measure the correlation between the data sets. The diagram shows that the correlation between the data in Tehran is very high, indicating that the data is closely related to each other. This high level of correlation makes it easier to predict the behavior of the data.

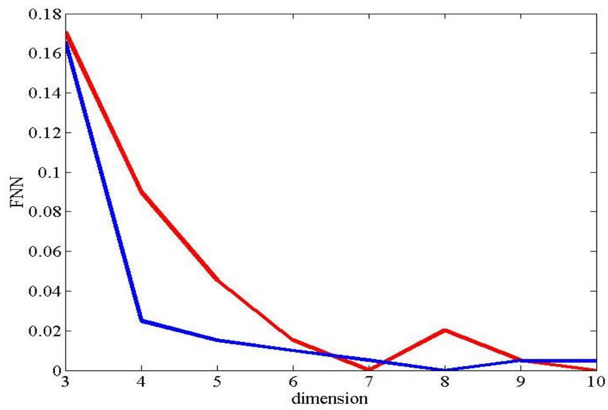
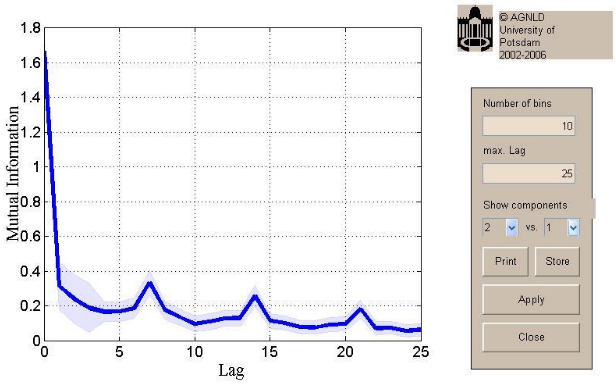
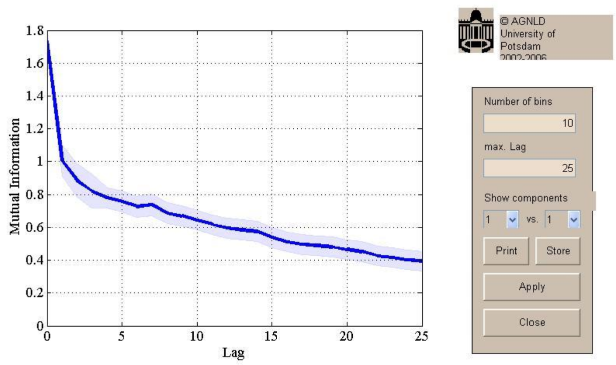


Figure 4. False Nearest Neighbor (FNN)



(a)

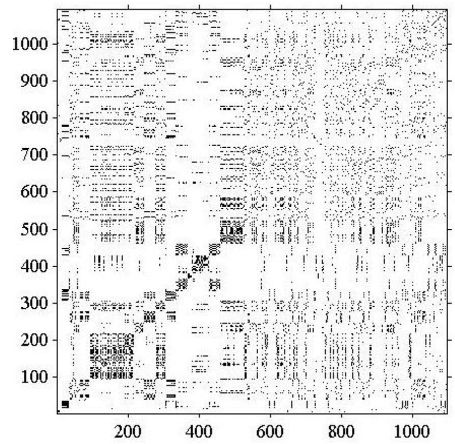


(b)

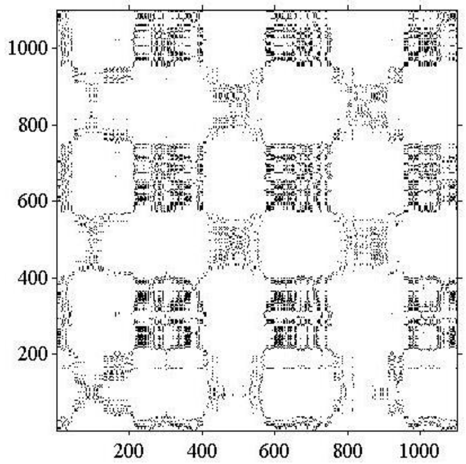
Figure 5. MI. (A) Tehran (b) Sistan

7. Power Spectrum Density

The power spectrum density diagrams in Figure 8 were generated using the psd (data) command. These diagrams show the distribution of power across different frequencies in the time series data. Specifically, the density spectral integral plots the average signal strength over a range of frequencies. This analysis can provide insights into the dominant frequencies present in the time series and can be useful in identifying periodic patterns or trends.



(a)



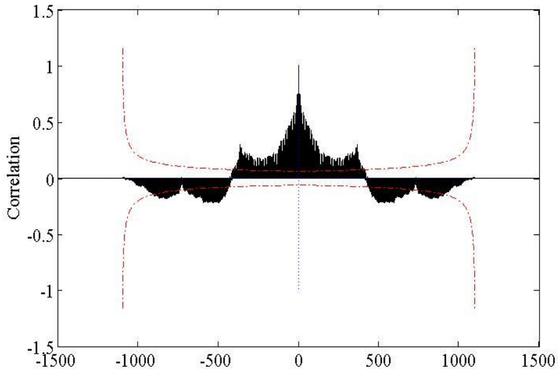
(b)

Figure 6. Diagram of cross recurrent plot (a) Tehran (b) Sistan

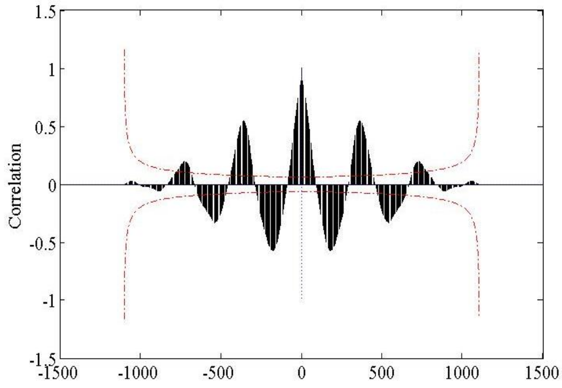
Figure 9 shows the phase space diagram for both time series in a 3D display. A phase space diagram is a useful tool for visualizing the behavior of a dynamical system in three dimensions. It plots the system's state variables against each other, with each axis representing a different variable. The resulting pattern of points can reveal the underlying structure of the system, such as periodicity, chaos, or other types of dynamics.

In this case, the phase space diagram shows that both time series exhibit chaotic behavior, as evidenced by the irregular and unpredictable pattern of points in the 3D space. This confirms the findings from the other methods used in this study, which also indicated that the time series are difficult to predict due to their chaotic nature.

Overall, the phase space diagram provides additional insight into the underlying dynamics of the power consumption time series and reinforces the need for sophisticated forecasting methods that can account for the complex and unpredictable behavior of these systems.



(a)



(b)

Figure 7. xcf diagram: (a) Tehran (b) Sistan

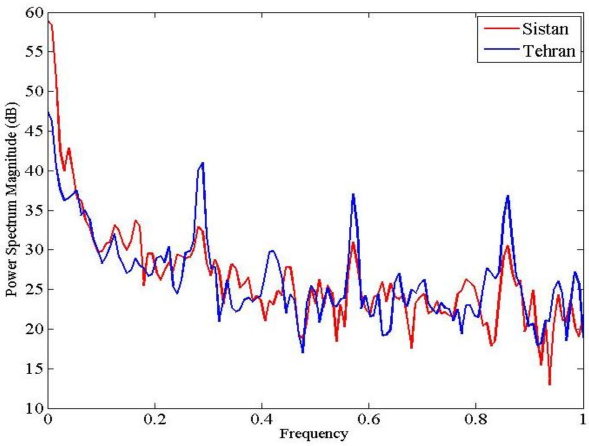
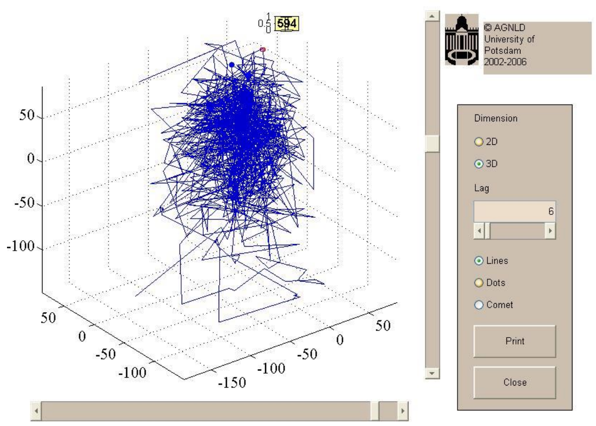
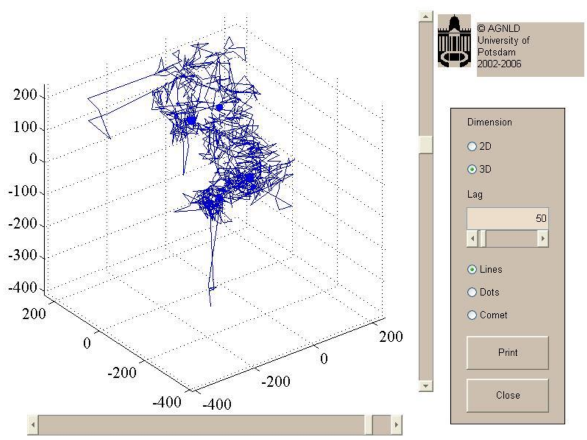


Figure 8. psd diagram of two time series



(a)



(b)

Figure 9. Phase body diagram for a) Sistan and b) Tehran time series

8. Conclusion

In this study, we analyzed and compared two-time series related to power consumption at 12 o'clock every day in 2020 and 2022 for two distribution networks in Sistan and one in Tehran. Our analysis revealed that the seasonal power consumption in Sistan is significantly impacted by weather conditions, as most power consumption in Sistan is due to household appliances. In contrast, power consumption in Tehran is less dependent on weather conditions and is driven more by the city's industrial nature, which makes it more predictable. We also found that the upward trend in power consumption in Tehran is primarily due to the city's faster development and population growth, whereas Sistan, being a deprived area, has not experienced many changes in power consumption during the two years. Finally, we observed that the difference in power consumption between seasons is more pronounced in Sistan compared to Tehran. Overall, our findings suggest that regional disparities in power consumption are closely linked to socio-economic and environmental factors, and further research in this area is needed to inform future policies and initiatives aimed at promoting sustainable development in different regions of Iran.

Ethical issue

The author is aware of and complies with best practices in publication ethics, specifically concerning authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The author adheres to publication requirements that the submitted work is original and has not been published elsewhere in any language.

Data availability statement

Datasets analyzed during the current study are available and can be given following a reasonable request from the corresponding author.

Conflict of interest

The author declares no potential conflict of interest.

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