The Future Electricity Demand Profile in Jordan in the year 2030

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Abstract: – This paper examines the electricity consumption pattern in Jordan during the period from 2007 to 2015 as a step for forecasting the daily electricity load curves (DLCs). The paper aims at (1) examining the alterations in system load profile of the country during recent past with emphasis on the seasonality of the annual and monthly loads, the day-to-day load pattern and the winter-to-summer variations and load duration curves (2) developing a technique to forecast the DLCs for a period extending to 2030. The forecast of the DLCs is based on the historical growth rates (GR%) of the actual hourly-loads in the period 2007 and 2014. Results show that the DLCs in Jordan is characterized by three periods: the minimum load prior to sunrise, daytime peak at around 13:00 and evening peak at around 18:00-20:00. The annual peak load during the period of study show dominant daytime peak occurrence. Prominent daytime peak was also observed in summer, particularly between 14:00 and 15:00 whereas dominant evening peak was seen in winter. The comparison between the actual and forecasted DLCs shows a minimal percentage errors with a values in the range of $\pm 3\%$.

Keywords: Daily load curve, Load profile, Load duration curve, Load forecast, NEPCO, Peak load, Energy
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1. Introduction

The electricity demand is an important indicator that is used to measure the development in any country. The analytical studies on power consumption are very important planning studies that are being conducted by power companies worldwide [1]. Such studies aim at: identifying the behavior of load curves and daily changes during several years, recognizing the periods of the peak load occurrence in summer and winter, identifying the sharing percentage of the daytime and nighttime consumption. One of the important planning studies for the power system in Jordan is the load forecasting studies that are prepared in daily, weekly, monthly, and annual basis [2][3][4]. Some studies are devoted on forecasting the daily electricity load curves by using the hybrid approaches e.g. Cho et al. [5]. The power companies seeking for an accurate electricity load forecasting to minimize the financial risk and to maximize the operational efficiency and reliability. Hammad *et. al.* [6] have classified the techniques used for electricity load forecasting such as: multiple regression, exponential smoothing, iterative reweighted least-squares, adaptive load forecasting, stochastic time series, ARMAX models based on genetic algorithms, fuzzy logic, neural networks, and expert systems [7][8]. The most common forecast methods are regression, reference, and time series analysis.

One of the main problems that face the interconnected power system of Jordan is the abnormal increase in the peak loads during the months of June to August in summer and during December to January in winter, which coincide with abnormal increase or decrease in ambient temperatures, respectively [1][9][10]. The abnormal increase in the peak load results in a reduction in the available spinning reserve; the spinning reserve for Jordanian power system during 2015 is about 22.6% with installed capacity and the peak load of 4266 MW and 3300 MW respectively [10]. Cartalis et al. [11] shows that the increase of ambient temperature by 1˚C above the mean value causes a decrease in the energy consumption required for heating by 10% during winter and increase in the energy required for cooling by 28.4% in summer. Shuvra et al. [13] summarized the factors that directly influence the change of electrical energy demand in any country by economic, demographic and technological factors, factors related to policy change and environmental factors.

Due to the scarcity of previous studies that interact with the consumption patterns of Jordan and forecasting of the daily electricity load curves (DLCs), This paper presents detailed analysis of the daily loads for several years starting from 2007 to 2015 with emphasis on the seasonality of the annual and monthly loads, the day-to-day load pattern and the winter-to-summer variations. A technique to forecast the DLCs is also presented in this paper. The paper is organized as follows: Section 2 presents the analysis of the actual DLCs in the period of the study 2007–2015, Section 3 presents the summer-to-winter load variations during the period of study. Section 4 introduces the DLC forecast method and ultimately Section 5 is the conclusion of the paper.

2. Analysis of the actual DLCs

The annual generation (in GWh) and the peak load (in MW) of both morning and evening periods during the period from 2007 to 2015 in Jordan is presented in Table 1. As shown in the table, the annual energy and peak load increased from 12787.12 GWh and 2130 MW in 2007 to 16765.65 GWh and 2975 MW in 2013 with growth rate of 31% for the energy and 39.6% for the peak load. Table 1, also shows that the peak load in 2007–2012 occurred in summer, particularly on July 29, 2007, August 19, 2008, July 29, 2009, August 3, 2010, July 31, 2011, and July 19, 2012, whereas in 2013 and 2014, it occurred in winter on December 17 and December 28, respectively. In 2015, the peak load occurred on August 4. According to the previous results, the annual peak load in Jordan generally occurs in summer, particularly in

July/August, and rarely occurs in winter, particularly in December/January (as in 2013 and 2014). As shown from the values of the annual growth rate for both the energy and peak loads over the entire period, the dramatic increase in peak load in 2011 could be attributed to demographic factors, such as Syrian immigrants to Jordan since 2011. The factors that mainly affect the electricity demand (in MW) in Jordan are detailed by several researchers elsewhere such as [1] and [7]. The load factor (LF%) is a measure of the utilization rate, or efficiency of electrical energy usage. Its value is always less than one because maximum demand is never lower than average demand. The LF% is defined as the ratio of average load in the billing period to the peak demand (KW) during the entire period as shown in Eq.1. The total billing hours in a year is 8760 hours (i.e 365 day per year x 24 hours per day). During the period of study and for Jordan case, the L_f% is in the range between 65% and 70%.

$$L_f(\%) = \left(\frac{E(GWh)x1000}{P(MW)x8760}\right)x100\% \quad (1)$$

Figure 1 presents the annual DLCs for the period 2007–2015. The values in the curves are obtained from the maximum hourly load in MW. The load sheet consists of 24 columns and 365 rows, that represents 365 days/ year and 24 hours/ day. The minimum load is usually occurring around 6:00 morning, followed by a morning ramp which continue until around noon time at 13:00 where a first peak load took place, we call it morning peak which is usually between 13:00 and 15:00 afternoon.

TABLE 1
ANNUAL ELECTRICITY GENERATION (IN GWH) AND PEAK LOAD (IN MW) IN JORDAN DURING 2007–2015 [11].

Year	Energy (GWh)	Peak load (MW)		*Overall Max. Peak* (MW)	Lf%
		Morning period	Evening period		
2007	12787	2130	2030	2130 (Jul. 29)	68.5
2008	13246	2141	2112	2141 (Aug. 19)	70.6
2009	13697	2208	2131	2208 (Jul. 29)	70.8
2010	14573	2544	2362	2544 (Aug. 3)	65.4
2011	15588	2660	2530	2660 (Jul. 29)	66.9
2012	16491	2770	2630	2770 (Jul. 31)	67.9
2013	16765	2840	2975	2975 (Dec. 17)	64.3
2014	17805	2845	2900	2900 (Dec. 28)	70.1
2015	18639	3300	3160	3300 (Aug. 4)	64.5

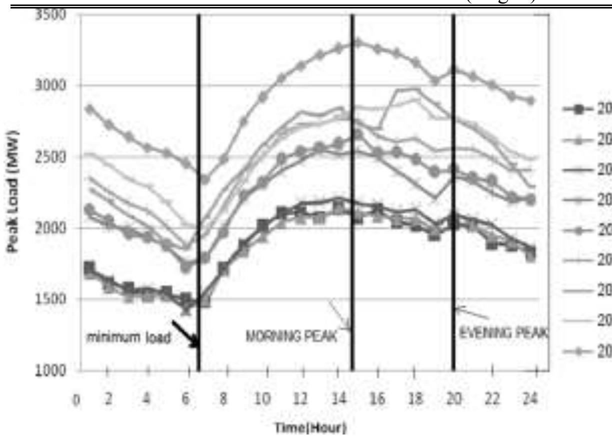

Fig. 1. The typical annual daily load curve for 2007–2015

Following the morning peak, the demand decreases gradually until sunset time where a second peak occurs. The second peak is called the evening peak which is usually between 18:00 and 20:00 evening. Based on Figure 1, the DLC is characterized by three periods: the minimum load prior to sunrise, morning peak at around 13:00 and evening peak at around 18:00-20:00. Usually, the morning peak is higher than the evening peak but in some years the evening peak is higher. Significant variations are observed in the 2013 curve where the peak load occurs in the evening period around 18:00, whereas the morning peak was dominant over the entire period of 2008–2012. Figure 2 presents the load duration curve (LDC) for Jordan in 2013. The curve is obtained by sorting the peak load readings in the year (365 readings) from lightest to lowest in descending order. The LDC is used in electric power generation to illustrate the relationship between generating capacity requirements and capacity utilization. The curve shows three periods of loads these are: the peak, intermediate and minimum or base load. The LCD has a relation with electricity pricing where the base load at the right side of curve is usually the least cost, whereas and peak load at the left side of the curve is the most expensive generation cost.

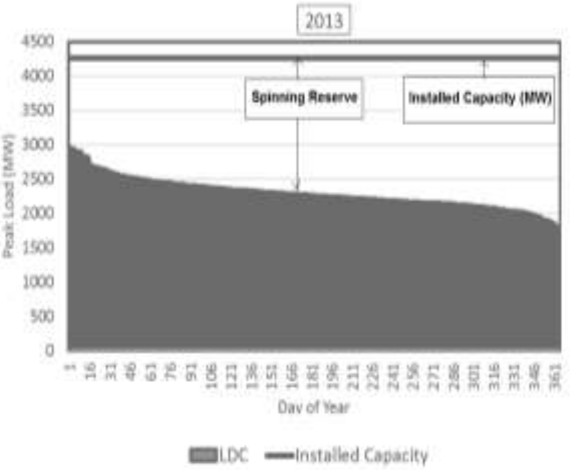

Fig .2 The load duration curves LDC in the year 2013

3. Summer to winter load variations in Jordan

The chart in Figure 3 presents the monthly energy consumption (GWh/Month) for 7-year period between 2007–2013. As shown in the figure, the highest consumption was seen during summer as seen in the middle of the column chart of each year, particularly in July–August and also in winter at the boundary of each year which represents December and January. The lowest consumption occurred during the autumnal and vernal equinox every year, particularly in April and October every year. The pattern shows similarities from year to year. The figure also show indication that the pattern is sensitive to high/low ambient temperature as was proven by several researchers elsewhere.

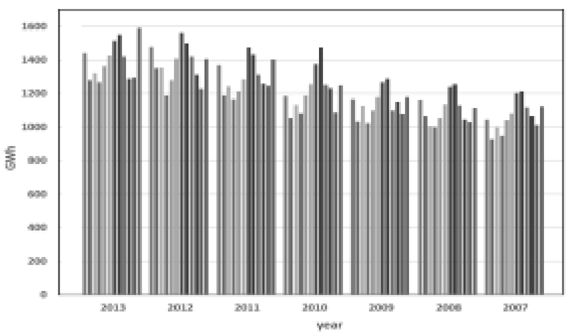

FIG. 3. THE MONTHLY GENERATION (IN GWH) IN THE PERIOD FROM 2007 TO 2013

In order to examine the season impact on the peak load occurrence, the DLC in a very warm month, e.g., August 2007–2015 was compared, with that in a very cold month, e.g., December 2007–2015. The comparison shows a variation in the peak load response between summer and winter season particularly in the occurrence time. Prominent daytime peak was observed in summer, particularly between 14:00 and 15:00 as shown in Figure 4(a), whereas dominant evening peak was seen in winter, particularly between 17:00 and 18:00 as shown in Figure 4(b). The occurrence of the daytime and evening peaks in these periods is mainly attributed to the environmental impact and the crushing use of air conditioning for cooling in summer and heating in winter. The seasonality of the load pattern is examined by different researchers elsewhere, such as Enrica De Cian et al. [14], who show that the seasonal pattern of energy and electricity consumption typically exhibits two peaks, one in winter and one in summer, with the summer peak becoming progressively higher in many countries in recent years. This suggests that the temperature interplays with other factors, like income, as demand for air conditioners requires a relatively high income elasticity, and different income elasticities are also associated with different fuels.

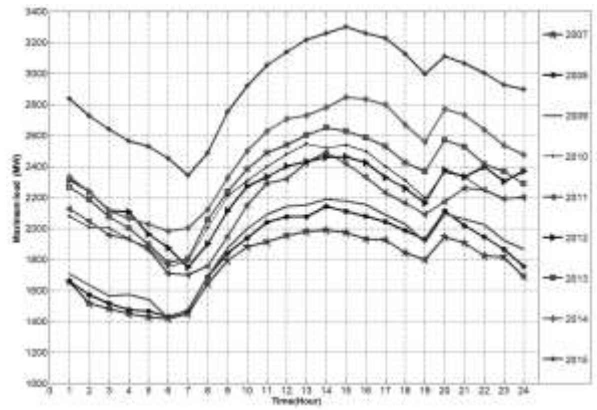

FIG. 4(A). THE TYPICAL DLC DURING AUGUST OF 2007–2015 (SUMMER)

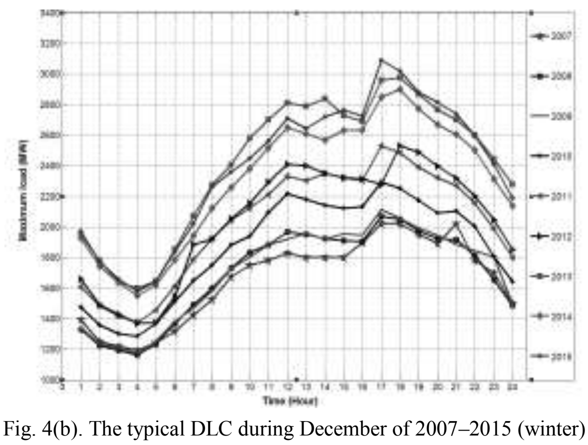

Fig. 4(b). The typical DLC during December of 2007–2015 (winter)

A comparison of the monthly DLC between 2007 and 2013 respectively are also examined as shown in Figure 5. The purpose of this analysis is to show the month-to-month difference. The figure shows significant variations between the two years. A progress in the evening peak is clearly seen in the year 2013 comparing with the year 2007. In 2007, the maximum peak was recorded in July with a value of 2130 MW whereas in the 2013 it was recorded in December with a value of 2975 MW. The figure also shows the daytime and evening peak are near to each other in the year 2013 while the difference is large for 2007.

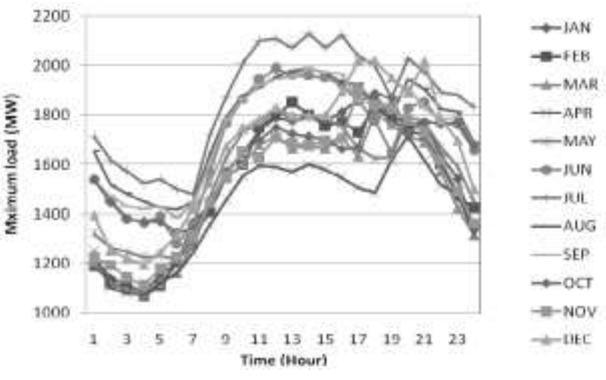

Fig. 5 (a). The typical monthly DLC during 2007 with the peak load in July

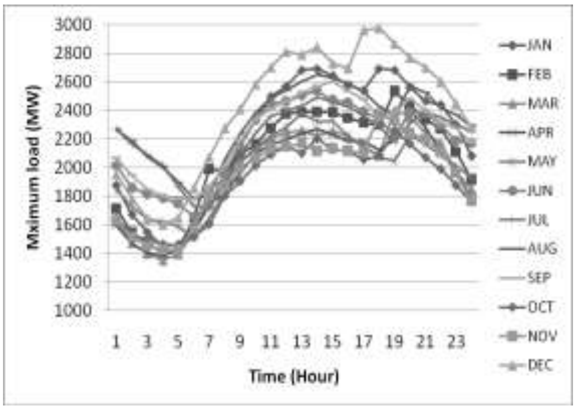

Fig. 5 (b). The typical monthly DLC during 2013 with the peak load in December

4. The DLC forecast

The future power profile for countries is different due to demographic and economic factors. Grandjean et al. [15] and Momani [1] declared that the future power demand profile will be completely different from that of today for many reasons, namely improved building insulation, new comfort levels and management scenarios in dwellings, and possible widespread integration of electrical heating systems that will replace old installed systems using fossil fuels, e.g., PV modules with battery. The quality of the forecast methods mainly depends on the available historical data as well as on the knowledge about the factors influencing the energy demand. This paper presents a technique to forecast the DLC based on the actual values of the long term forecast study made by NEPCO presented in Table 2. The historical growth rates (GR%) between 2007 and 2014 are used in forecasting the DLCs for Jordan case. The analysis is based on two scenarios of peak occurrence: morning peak occurrence and evening peak occurrence as shown in the procedure.

4.1. The procedure:

Table 2 presents the forecasted annual energy (In GWh) and peak load values (in MW) obtained from the long term load forecast study of NEPCO [2] during the period of 2017–2030. The table shows a normal growth rate of 4–5% for the energy and 5–6% for the peak load. The analysis assumes that a peak load with the same value may occur during either the morning or evening periods of the day, particularly between 13:00 and 15:00 for the morning peak and 18:00 and 20:00 for the evening peak.

TABLE 2

THE ANNUAL FORECASTED ENERGY AND PEAK LOAD FOR THE PERIOD BETWEEN 2017 AND 2025 AS OBTAINED FROM NEPCO [2]

	ENERGY		PEAK LOAD	
YEAR	GWh	GR%	MW	GR%
2012 (Actual)	16491		2770	
2013 (Actual)	16765	1.66%	2975	7.4%
2014 (Actual)	17805	6.20%	2900	-2.5%
2015 (Actual)	18639	4.68%	3300	13.8%
2016 (Actual)	19385	4.00%	3190	-3.3%
2017	20354	5.00%	3678	15.3%
2018	21371	5.00%	3899	6.0%
2019	22440	5.00%	4133	6.0%
2020	23562	5.00%	4340	5.0%
2021	24740	5.00%	4600	6.0%
2022	25730	4.00%	4876	6.0%
2023	26759	4.00%	5169	6.0%
2024	27829	4.00%	5479	6.0%
2025	28942	4.00%	5780	5.5%
2026	30100	4.00%	6011	4.00%
2027	31304	4.00%	6252	4.00%
2028	32556	4.00%	6502	4.00%
2029	33858	4.00%	6762	4.00%
2030	35212	4.00%	7032	4.00%

In order to forecast the DLCs of the coming years the following procedure was implemented:

a) Determine the historical growth rate over a period of the study from 2007-2014 by using Eq. 2.

$$GR\% = \left(\frac{P(t_r)}{P(t_0)}\right)^{\frac{1}{n}} - 1 \qquad (2)$$

where:

t_o : Reference year which represents starting of the period with actual data (e.g 2007)

t_r : Target year which represent end of the period with actual data (e.g 2014)

n: The period, in our case 7 years' period.

$P(t_r)$: Hourly peak load in the target year (in MW).

$P(t_0)$: Hourly peak load in the reference year (in MW)

The equation produces a matrix of 24 rows and 365 columns which 24 hours /day and 365 days / year.

b) Smooth the values obtained in Eq.1 by moving average technique through averaging the hourly readings of three days: same day, day before, and the day after.by using Eq. 3.

$$GR_0\% = \frac{GR(t-1)\% + GR(t)\% + GR(t+1)\%}{3} \quad (3)$$

where $GR_0\%$: the smoothed GR% values

c) Obtain the hourly forecasted peak load in m-year namely $P(m)$ in MW based on the smoothed GR value by using the following formula:

$$P(m) = (k \times GR_0\% + 1)^n \times P_{(tr)} \quad (4)$$

where:

where k= $\frac{GR(_{f-r})\%}{GR(_{r-0})\%}$: adjustment factor represents the ratio between the forecasted annual energy to the annual energy in the reference year $GR(_{f-r})\%$ divided by the ratio of the annual energy in the target year to the annual energy in the reference year $GR(_{r-0})\%$. This factor is closed to 1 and it may be greater or less. The importance of this factor is to cover the period of study by considering the variation from year to year and also to ensure that the summation of hourly loads over the year is in agreement with the forecasted annual value obtained by NEPCO.

d) Obtain the forecasted annual energy in the m-year in GWh by using the formula:

$$E_f(m) = \frac{P(m)}{1000} \times 8760 \times L_f \quad (5)$$

where L_f is the annual estimated load factor of NEPCO, which is for Jordan in the range 0.65–0.7.

Figure 6 presents the forecasted versus actual peak load for the year 2015. As shown in the figure, the two curves followed each other with a percentage error of $\pm 3\%$. The figure shows a residual difference between the actual and forecasted readings too where the maximum difference was seen during the morning periods and post-midnight period and this is because the forecasted curve considers the responses of all previous years covering the study.

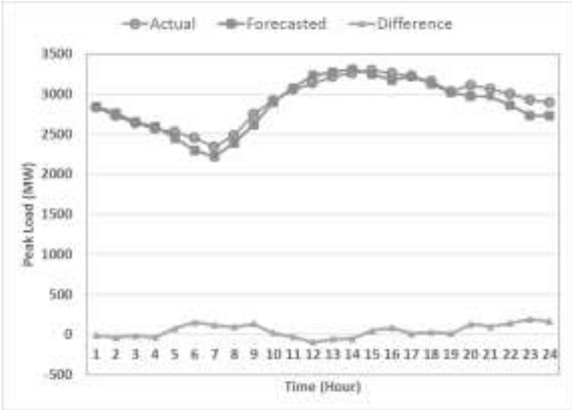

Fig. 6. The forecasted and estimated peak load based on the procedure used in 2015(actual year)

The suggested formulated that are used in prediction the DLCs in Jordan consider two scenarios of the peak load occurrence those are: the daytime peak load occurrence or evening time peak load occurrence as shown in Figure 7 and Figure 8 respectively. This assumption is due to the reality of peak load occurrence during the last decade. Figure 7 presents the forecasted typical annual DLCs for the period from 2015–2025, by assuming an evening peak occurrence, whereas Figure 8 assumes a morning peak occurrence. By comparing the two figures, it is clearly seen that the peak value in both curves does not change but it may be occurred in either evening or daytime period. The annual growth rate from year to year agree the values predicated by NEPCO which is the range of 5–6% as shown in Table 2. In the year 2025, the expected peak load and energy are 5800 MW and 28942 GWh respectively.

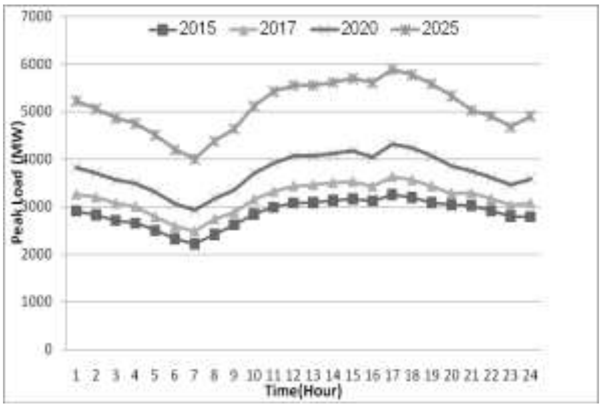

Fig. 7. The forecasted peak load from 2015-2025 by assuming evening peak occurrence

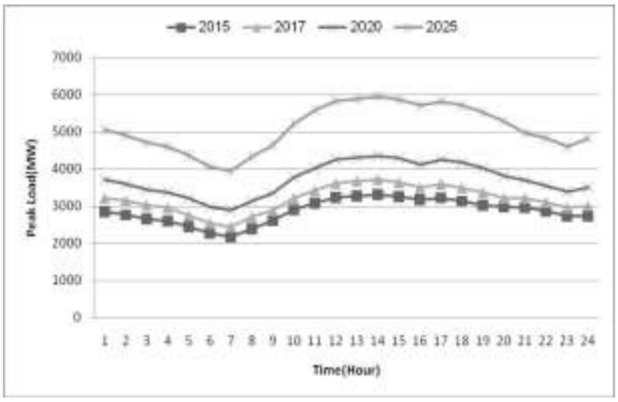

Fig. 8. The forecasted and estimated peak load from 2015-2025 by assuming morning peak occurrence

5. Conclusion

This paper presents a detail analysis on the electricity consumption pattern in Jordan for several years between 2007 and 2015 with emphasis on the seasonality of the annual and monthly loads, load duration curves, month-to-month and the winter-to-summer variations. The paper also introduces a technique to forecast the DLCs based on the historical growth rates (GR%) and on the long term forecast study made by NEPCO. The results show that typical DLCs for Jordan case are characterized by three periods: the minimum load, daytime peak and evening peak with a variation in the peak occurrence time between summer and winter. During summer, the annual peak load is usually seen during daytime period, whereas during winter it is seen evening period, which is mainly attributed to the environmental impact and the crushing use of air conditioning for cooling in summer and heating in winter. The comparison between the actual and forecasted DLCs shows a good consistency all over the period of study with a percentage error in the range of $\pm 3\%$. The proposed technique is simple and usable and can be used for any period of time.

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