Estimation of Time drift in Interface energy meters

Mastanvali Shaik
WRLDC,POSOCO
Mumbai, India
mastanvali.nitw@gmail.com

Vivek Pandey
NLDC,POSOCO
Mumbai,India
vivek.pandey@posoco.in

Sushrut Meshram
WRLDC,POSOCO
Mumbai,India
sushrut.meshram@posoco.in

Sunil Kumar Aharwal
WRLDC,POSOCO
Mumbai, India
skaharwal@posoco.in

Sachala Mishra
WRLDC,POSOCO
Mumbai,India
sachalamishra@posoco.in

Velury Balaji
WRLDC,POSOCO
Mumbai,India
vbalaji@posoco.in

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***Abstract*— Time drift in the internal clock of the Special Energy Meters (15-minute interval meter) installed for measuring inter-utility energy exchanges in India is a major concern in energy accounting and deviation settlement. Since the meter clock is accessible only locally, the time drift can only be determined locally by visually comparing the time in the internal clock of the meter with the Indian standard time. Collection of information related to meter time drift every week from the locations where these meters are installed, is a cumbersome process and it is also prone to errors due to manual intervention in data collection. This paper shares the various techniques being applied presently for determination of time drift and proposes a novel application of cross correlation with linear interpolation (used in signal processing) for estimation of meter time drift at the data collection centre. The efficacy of the proposed method has been demonstrated with the help of simulations. The novel application has been successfully used in Western Regional Load Despatch Centre in India and is found to be accurate to +/- 1 minute with a reasonable confidence level. The whole process of time drift estimation has been automated to significantly improve the energy meter asset administration.**

Keywords*—Cross Correlation, Deviation Settlement, Energy Accounting, Interface meter, Interpolation, Phasor Measurement Unit, Signal Processing, Special Energy Meter, Time drift,

I. Introduction

The Availability Based Tariff and Unscheduled Interchange mechanism (ABT/UI) at the interstate level in India mandated by the Hon'ble Central Electricity Regulatory Commission vide its order in January 2000 brought a paradigm change in the inter-utility energy accounting. The accumulation type energy meters (mechanical) at the inter-utility interface points were replaced by 15-minutes interval meters (Special Energy Meters, digital). The Special Energy Meter is capable of measuring active/reactive energy, voltage and grid frequency accurately and in a tamper-proof manner in pre-defined time interval of 15-minutes (one time block) [1]. The meter data is downloaded every week with the help of a hand-held unit through the optical port and transferred over email to the control centre in an encrypted format. The encrypted meter data received at Regional Load Despatch Centre (RLDC) is decoded through the proprietary software provided by meter vendors. Data validation and processing is through an in-house software. The inconsistent/erroneous data of main meter found during pair checking is replaced with the data from corresponding check/standby meter [2]. The processed meter data is used for energy accounting and weekly deviation settlement.

Deviation for a time block is calculated as actual energy interchange minus scheduled energy interchange. So, the deviation depends on energy scheduled by the utility & actual energy recorded by SEMs.

Each SEM has a built-in calendar and clock, which is required to have an accuracy of 30 seconds per month or better as per regulation [2]. These SEMs lack the capability to automatically synchronise with the reference time. Hence, the internal clock in the meter drifts from the standard time. The mismatch between the meter clock and the standard time is generally referred to as *"Time drift"*. The time drift in SEM can be corrected manually through Data Collecting Device (DCD) in steps of 1 minute per week, which is distributed to 6 consecutive time blocks with 10 seconds time correction in each time block. If the SEM clock is not regularly corrected to match standard time, then time drift gets accumulated and may introduce error in energy accounting and deviation settlement.

II. Impact of Time Drift in Energy Accounting

Large time drift in the meters may introduce unwanted errors in the energy accounting. An illustrative case described in [3] is reproduced as Fig 1 and Fig 2. From these figures, it may be seen that, the time drift leads to erroneous recording of line flows. Consequently, injection/drawl computations and the deviation accounts computed from this SEM data would be incorrect. Spikes in Transmission loss is observed due to time drift and it is further aggravated when there is sudden change in flow direction over the transmission line [4 ... i

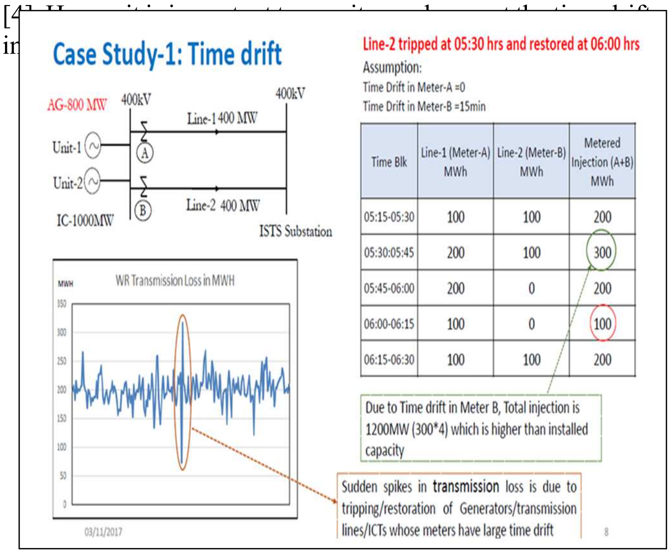

Fig. 1. Effect of time drift on actual injection/drawal [3]

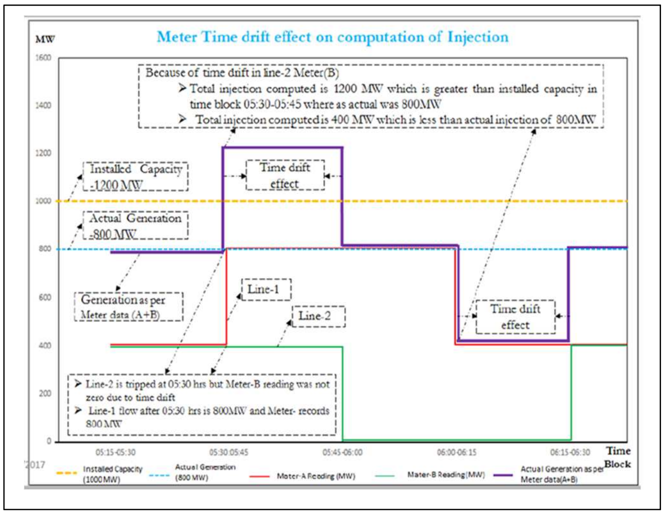

Fig. 2. Effect of time drift on actual injection/drawal [3]

III. Meter Time Drift Determination at Substation

The most common method to assess the time drift in the meter is by comparison of the time indicated by the internal clock of the SEM with the reference/standard time. However, the existing SEMs have a limitation that the meter clock is accessible only locally. Thus, the time drift can only be determined locally by visually comparing the time in the internal clock of the meter with the standard time. Collection of the above information at the central location every week is a cumbersome process, and it is also prone to errors due to manual intervention in data collection.

IV. Time Drift Estimation at Data Collection Centre

The meter data collected at the RLDC is validated by pair checking. Difference between main meter and check meter data aggregated on monthly basis shall not be more than 0.5% [3].The pair-checking can also be done through grahical method.

A. By comparing active energy graphs of meter pairs

Time drift could be visualized as a phase shift when corresponding pair of Main-Standby or Main-Check meter data is plotted as shown in Fig. 3. This method works well if only one of the two meters is time synchronized. However, if both the meters in the pair have equal time drift then the phase shift would not be visible at all. This method also fails to distinguish the meter that has time drift.

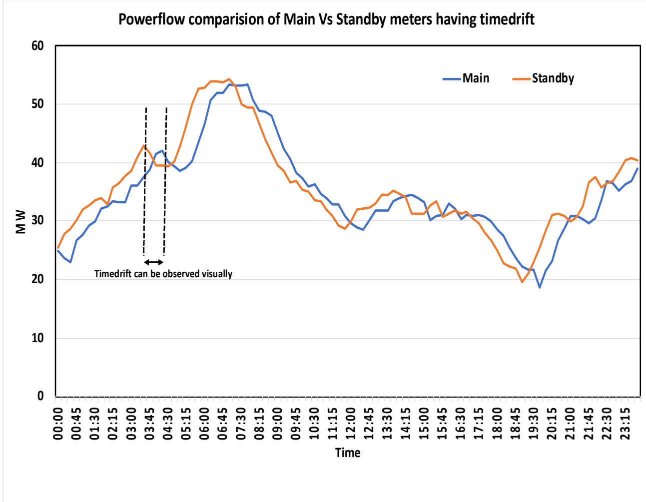

Fig. 3. Comparison of power flow of main and standby meter having delay between recordings

B. By comapring average frequency graphs

During steady state, the average frequency recorded in all time synchronized SEMs within a synchronous system would be same. The average frequency at 15-minutes interval is recorded as a two-digit code (varying from 00-99). This is converted into absolute value of frequency for deviation settlement. Comparison of the average frequency recorded in different meters with the frequency recorded by the reference meter would indicate the meters having time drift. An example is provided in Fig. 4.

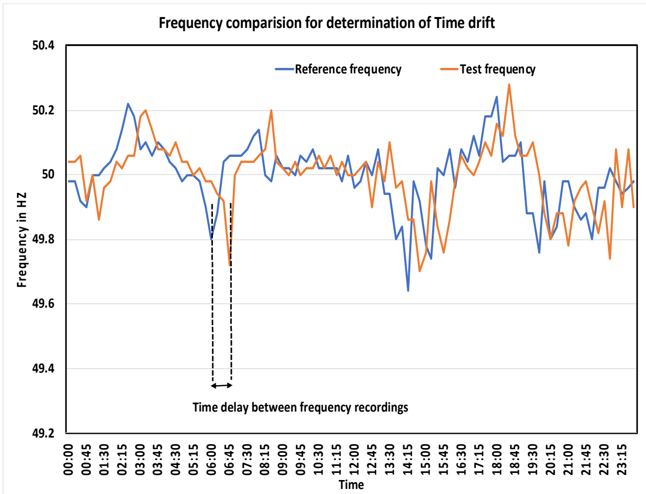

Fig. 4. Comparison of frequency recordings of reference meter and test meter with time drift

Both graphical methods indicate the existence of time drift in the meter but fail to quantify the same.

In order to quantify the time-drift, the techniques deployed in signal processing were studied and applied on energy meter data. Cross correlation was one of those techniques which provided encouraging results for time drift estimation of energy meters. The technique is described in Section. V

V. APPLICATION OF CROSS CORRELATION FOR TIME DRIFT ESTIMATION IN SEMS

The cross-correlation method is generally used for measuring similarities between two signals [5]. The correlation value peaks at a position where the similarity between the signal is high. If the signals are periodic, multiple peaks can be observed.

The average frequency data of reference meter and test meter were considered as signals to assess the similarity. The cross correlation of these signals was implemented in Python using Numpy and Scipy libraries which have FFT, IFFT (Fast Fourier Transform and Inverse Fast Fourier Transform) capabilities.

An example case is shown in Fig 5.

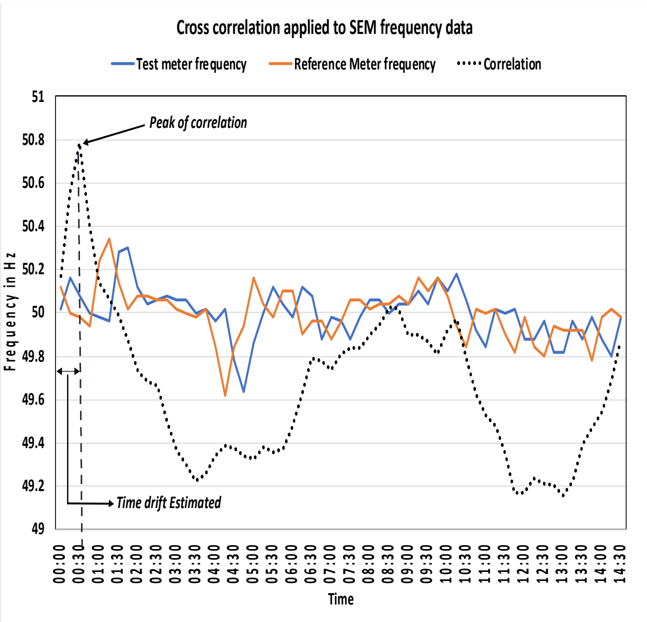

Fig. 5. Cross correlation of two frequency signals having time drift

It may be seen from the Fig.5 that the value of cross correlation peaks at 30 minutes. This could be considered as the approximate time drift in the test meter. However, since the resolution of the signal is 15 minutes, the time drift assessed from the above method would be in multiples of 15-minutes. Therefore, the above method was further improved to estimate the drift at a higher resolution.

The reference signal and test signal available at the resolution of 15 minutes were linearly interpolated (as shown in Fig 6) and then the cross-correlation method was applied to estimate the time drift at a resolution of 1 minute.

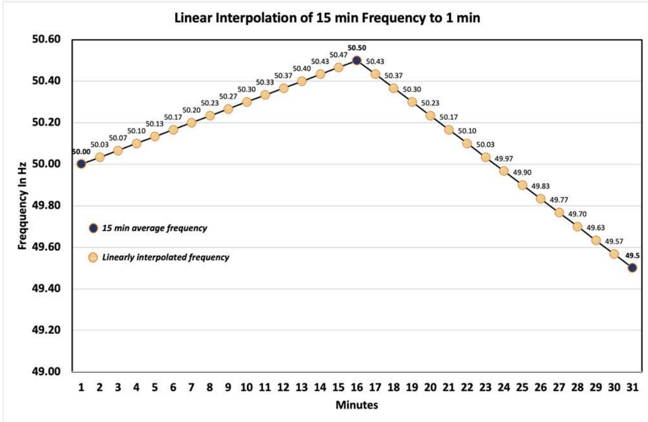

Fig. 6. Linear interpolation

The flow chart for finding the time drift is provided below.

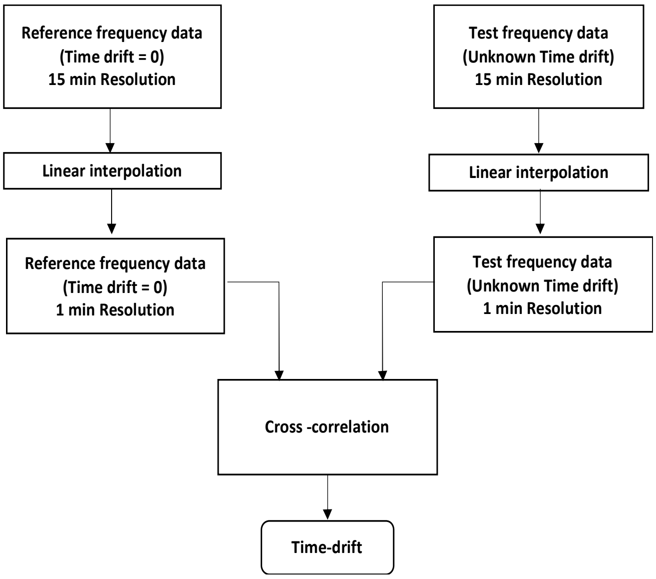

Fig. 7. Procedure for finding time drift

In order to assess the confidence level of the time drift estimated through cross correlation method applied on linearly interpolated frequency signals from the energy meter, the results were tested through simulations as explained in the next section.

VI. SIMULATIONS TO ASSESS THE CONFIDENCE LEVEL

Several Phasor Measurement Units (PMUs) are installed in the grid for visualization of power system dynamics in the Indian grid. The PMU measurements are time synchronised. The PMU could be considered as sub-standard meter for a limited purpose. In order to create the reference signal required for cross correlation, the 1 sec frequency measurements were averaged to get 15-minutes average frequency. Multiple test signals were generated by introducing phase shifts of varying magnitude (-60 minutes to +60 minutes) in the 1 second frequency measurements from PMU and averaging it to obtain 15 minutes frequency data. The simulated test signals mimic the frequency recordings of SEMs having time-drift.

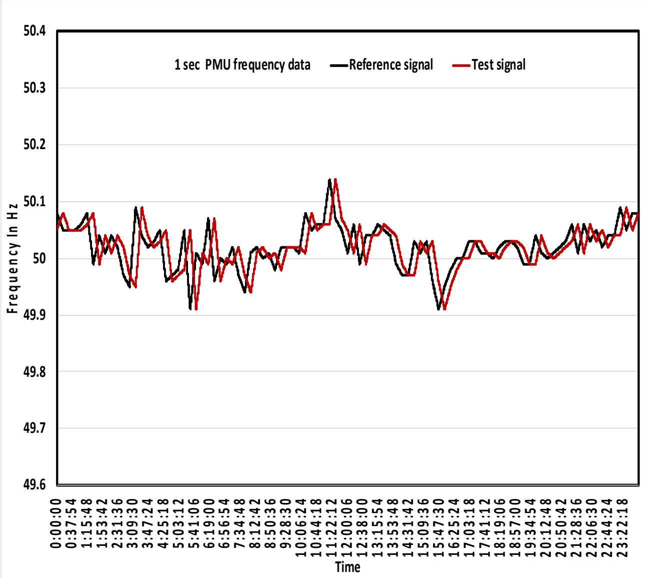

Fig. 8.Raw value, reference signal and simulated signal from PMU data.

Simulations were done using Python scripts. The flow chart for the Simulation exercise is illustrated in Fig.9.

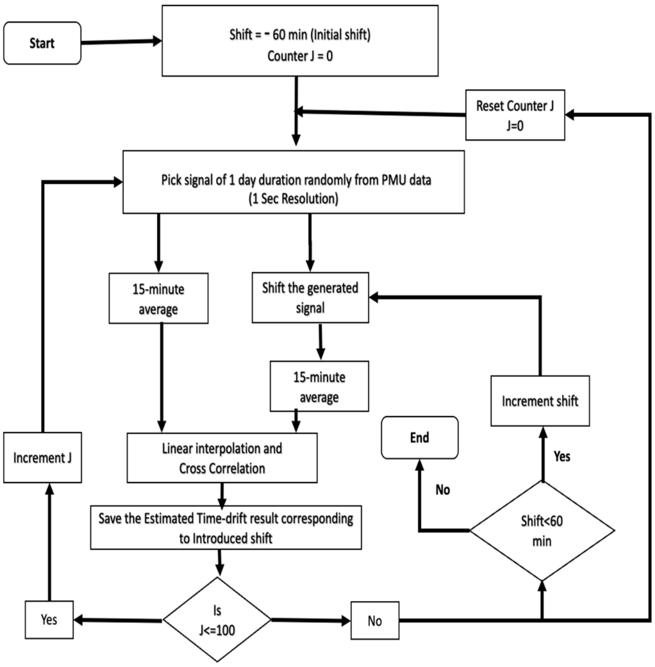

Fig. 9. Procedure for simulating the time drift estimation

The simulation was done for each introduced time drift (shift) in the range of -60 minutes to +60 minutes. For each value of shift, the shift was introduced in 101 randomly picked frequency signals from the PMU data and the time drift was estimated.

Results of the simulation:

The percentage of trials where the estimated time drift is within range +/-1 minute to actual time drift introduced are as below:-

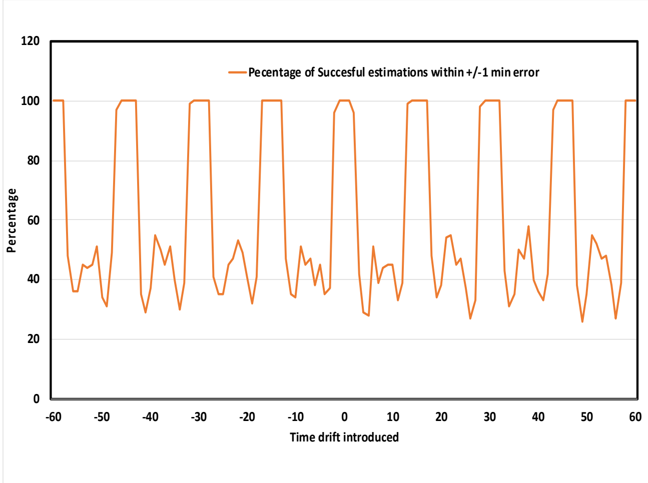

Fig. 10. Percentage of successful time drift estimations with +/- 1 minute error

From fig 10, it can be observed that the estimated time drift tends to be more accurate when the introduced time drift is closer to multiples of 15 minutes.

Another simulation was done for 20000 random trials, introducing random time drift from -120 minutes to 120 minutes for each trial and estimating time drift. The results of simulation are as given below:-

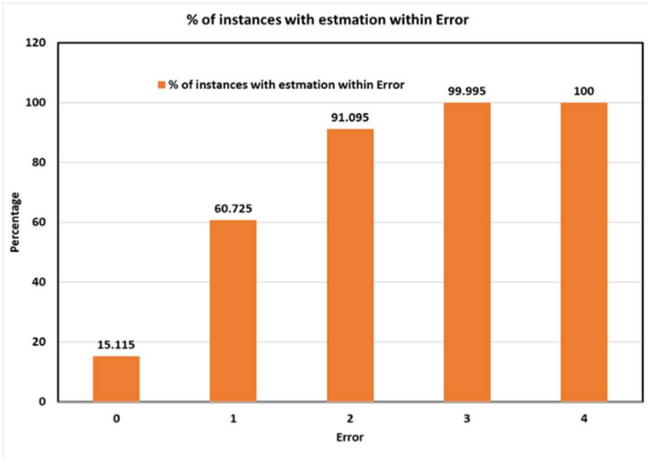

Fig. 11. Simulation results with random trials

In the simulations, time drift in the range of -60 to 60 minutes was given to the PMU frequency signal. This shifted signal was then cross correlated with the reference signal and the results were noted. Successful estimation of time drift with +/-1 minute error is more than 40 % for most of the trials. Successful estimation of time drift with +/- 2 minutes error is at more than 70 % for most of the trials.

For simulation done with 20000 random trials, introducing random time drift from -120 minutes to 120 minutes for each trial for estimating the time drift. The results were 60.725% times within +/-1 minute error range, 91.095% times within +/-2 minutes error range and 99.995 % times within +/-3 minutes error range. Thus, it may be inferred that the time drift estimated with the help of cross correlation of frequency from the reference meter and the linear interpolated frequency data from the test meter is reasonably reliable. The technique could be used to quickly identify the meters with large time drift and subsequent follow up with the substation personnel for time-drift correction.

VII. SUMMARY

There are 7804 number of SEMs in interstate transmission system in India [6]. The number of meters in intrastate system will be much higher. The SEMs lack capability to auto synch with the standard time and hence are prone to time drift. Time drifts introduce discrepancy in the computation of drawl/injection of the utilities. Hence, regular monitoring and correction of the time drift is very essential. The time drift can be ascertained accurately at site by visually inspecting the time of SEM clock. However, the time drift estimation of meters remotely is also very helpful. The time drift can be identified by visual inspection of power flow/frequency of main and standby/check meter pairs. Cross-correlation method on linearly interpolated frequency signals is very helpful in the determination of time drift at a resolution of 1 minute with a reasonably good confidence level.

SUGGESTIONS FOR FUTURE

Due to the challenges faced with existing 15 minutes interval SEMs and due to advantages of 5 minutes, the replacement of 15-minutes SEMs with 5-minutes meters is contemplated. The envisaged 5-minutes meters are capable of auto synchronization with standard time. With the large-scale integration of renewable energy sources at both interstate and intrastate transmission level, the number of meters is expected to grow. Advance methods for bad data detection are required to be adopted for the validation of meter data.

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REFERENCES

[1] Vivek Pandey, Akhil Gupta, C. Jagadessh, V. K. Shrivastava, Interface Energy Metering System – Experience and Recent Initiatives in India. Metering India 2019 - 8th International Seminar on Energy Meters https://www.researchgate.net/publication/335096392_Metering_India_2019_8th_International_Seminar_on_Energy_Meters

[2] CEA (Installation & Operation of Meters) Regulations, http://www.cea.nic.in/meteringreg.html

[3] Vivek Pandey, Akhil Gupta, Ch. Jagadeesh, 'Interface Energy Metering Experience and Expectations', Central Board for Irrigation and Power and National Smart Grid Mission, Workshop on "Technical and Testing Challenges for Smart Meters", http://cbip.org/Smart%20Meter%20November%202017/Dat a/9.pdf

[4] Verma, Umesh & Chakraborty, Goutam & Ahmad, Nadim. (2015). Role of Special Energy Meter on Deviation Settlement. https://www.researchgate.net/publication/327859400_Role_of_Special_Energy_Meter_on_Deviation_Settlement

[5] Derrick, Timothy R. and Thomas, Joshua M., "Time Series Analysis: The Cross-Correlation Function" (2004). *Kinesiology Publications*. 46. https://lib.dr.iastate.edu/kin_pubs/46

[6] Power system opertation corporation (POSOCO) Report on pilot project Five minute metering and Accounting in India. https://posoco.in/wp-content/uploads/2021/02/Report-on-Pilot-project-–-Five-Minute-Metering-and-Accounting-in-India.pdf