Abstract—This paper provides initial justification for adopting a distributed architecture for phasor measurement unit. The characteristics of synchronized phasor measurement is studied in detail. The benefits and short comings of phasor measurements are highlighted from the point of view of their different applications. The need for extension of phasor measurement unit functionality is brought out through analysis of the application and synchronized phasor measurement characteristic compatibility. The concept of phasor measurement unit is extended to a distributed system with several small functions working independently to provide a complete functionality of a phasor measurement unit. The proposed substation automation works on the framework of IEC 61850 process bus.

Index Terms—Discrete Fourier Transforms, Filters, Out-of-Band, Power Swings, Modulations, Substation Automation, Phasor Measurement Unit, Distributed State Estimation, Process Bus.

I. INTRODUCTION

The idea of Phasor Measurement Unit (PMU) as a single physical device providing measured voltage, current and frequency output to Phasor Data Concentrator (PDC) is well suited if the purpose of the PMU is to supplement or replace the measurements of Remote Terminal Units (RTU) for a centralized state estimation. The utility of phasor measurements can be greatly extended if its output is used not only in monitoring but also in control and protection. The requirements of monitoring, control and protections can sometimes be widely varying and a single PMU device may not be able to serve all purposes. So we envisage a distributed PMU architecture where it becomes capable of providing different applications with suitable inputs.

In the following sections, we start with description of existing PMU configuration, discuss its extension and then provide details of the applications like local state estimation, use of non conventional instrument transformer like Rogowski coils for monitoring, control and protections can sometimes be widely varying and a single PMU device may not be able to serve all purposes. So we envisage a distributed PMU architecture where it becomes capable of providing different applications with suitable inputs.

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II. THE PHASOR MEASUREMENT UNIT

The applicable standard for PMU is [1]. It addresses the definition of a synchronized phasor, time synchronization, application of timetags, method to verify measurement compliance with the standard, and message formats for communication with a PMU. In this context, a PMU can be a stand-alone physical unit or a functional unit within another physical unit. More importantly, this standard does not specify hardware, software or a method for computing phasors. It specifies data formats and synchronization requirements to allow correlating phasors from various sources and compares them with similar data from different measurement systems.

Most of the implementations of this standard is in form of an Intelligent Electronics Device (IED) [2]–[7]. It is a generally a single unit which accepts the inputs for Current Transformer (CT), Voltage Transformers (VT) and some binary inputs. The output of a PMU is phasor representation of the measured sinusoidal quantities with a precise time stamp. The binary signals too are given out with time stamp attached. These outputs are generally communicated to a PDC, where such outputs from several other substations are collated. In several places the PMU is considered equivalent to a disturbance recorder which measures the phasors and stores it locally as well as transmit it outside the substation.

For the purpose of state estimation and other similar applications, the PMU is viewed as a device which provides precise positive sequence voltage and current phasor values. From this point of view when a PMU is placed at a bus, its voltage and all the currents of the connected branches become observable. It is required that a PMU provides very good accuracy for steady state conditions i.e. the conditions in which state estimation is required to perform well. The time delay encountered in achieving such accuracy is not considered as critical performance criteria as the assumptions is that PMU is measuring a steady state condition. The range of measured voltage and current signals is usually within zero to rated value. The standard notion of state estimation can itself be extended to take full advantage of high rate of measurements obtained through PMUs. For example [8], consider linear state estimation for improving security of backup protection. Also there are applications for three phase state estimators for measuring unbalance in the system due to untransposed transmission lines.

For the purpose of wide area protection systems it is generally required that not only positive sequence quantities but also individual phase voltages and currents are available. Moreover, to be able to perform in a useful time frame it
may be required that these phase quantities are available with shortest possible delay. It may be possible that some accuracy is sacrificed in achieving fast phasor calculation. But at same time the same level of accuracy must be maintained for wider range of signals.

The present standard [1] does not fully address the requirements for protection. While there are no restrictions for PMU manufacturers to provide outputs as required by protection purpose, at same time there are no benchmarks nor minimum requirements nor any interoperability guidelines which can be followed. The future standards would sooner or later come up with such requirements. In such conditions it is prudent to design the PMUs and associated system such that it be easily adopted for any future standard requirements.

III. SYNCHROPHASOR MEASUREMENT

The pure sinusoidal waveform \( x(t) = X_m \cos(\omega t + \phi) \) is commonly represented as a phasor \( X = X_r + jX_i = (X_m/\sqrt{2})e^{j\phi} \), where \( \phi \) depends on the definition of the time scale, [1]. The phasor representation of a sinusoid is independent of its frequency. The phasors are called synchrophasors when a common definition of time scale is adopted for phasor representation of all the phasors. [1] has adopted phase representation synchronized to Universal time coordinated (UTC). The angle \( \phi \) is defined to be 0° when the maximum of \( x(t) \) occurs at the UTC second rollover. Hence, \( \phi \) is instantaneous phase angle relative to a cosine function at nominal system frequency synchronized to UTC.

Out of several methods employed historically the Discrete Fourier Transform (DFT) based algorithm is the most preferred way for estimation of a phasor from a sampled signal. Equation (1) represents one cycle, centered DFT algorithm for phasor estimation [9].

\[
\hat{X} = \frac{\sqrt{2}}{N} \sum_{k=-N/2}^{N/2-1} x[t_n + \Delta t(k + 1/2)] e^{-j(k+1/2)\frac{2\pi}{f_0}} \tag{1}
\]

Where, \( \hat{X} \) is the phasor estimate, \( x[t_n + \Delta t(k + 1/2)] \) are samples of signal \( x(t) \) taken at time \( t = [t_n + \Delta t(k + 1/2)] \), \( N \) is even number representing number of samples per cycle. The phasor is related to nominal frequency of the signal \( f_0 \) by selecting \( \Delta t \) equal to \( 1/(N.f_0) \). We define sampling frequency \( f_s \) as \( 1/\Delta t \). It is implicit in the equation that samples are obtained at a uniform sampling frequency. The angle \( \phi \) of \( \hat{X} \) is related to time \( t = t_n \).

The basics of phasor estimations are provided in [10], [11]. The properties of DFT based methods and its error analysis in face of input errors in sample measurements are discussed. For sake of brevity it is not reproduced here. But we can summarize the major conclusions here. For accurate estimation of the signal it is required that input signal is band limited and the sampling frequency is greater than twice the band width, i.e. Nyquist criteria is met. It has to be emphasized that this sampling theorem is pertaining to the input signal and the sampling frequency, and has no relationship with phasor estimation method. If the measurement error is random with uniform distribution around the true value of a sample, then estimation using larger number of samples would help in limiting the error in output phasor. The phasor calculation is not affected, if the input signal consists of extra frequency components that are integer multiples the fundamental frequency, such component are usually called harmonics.

A. Synchrophasor Estimation at Off Nominal Frequency

It can be shown that the phasor estimation through full cycle DFT will have errors in both magnitude and phase if the \( N \) samples are not uniformly spread over the full cycle of signal. The frequency response of phasor estimation through DFT in per unit is shown in 2, [11].

\[
\hat{X} = e^{j\phi} e^{j\pi(\frac{1}{f_0} - 1)} \frac{\text{sinc} \left[ \pi \left( \frac{f_s}{f_0} - 1 \right) \right]}{\text{sinc} \left[ \pi \left( \frac{f_s}{f_0} + 1 \right) \right]} + e^{-j\phi} e^{-j\pi(\frac{1}{f_0} - 1)} \frac{\text{sinc} \left[ \pi \left( \frac{f_s}{f_0} + 1 \right) \right]}{\text{sinc} \left[ \pi \left( \frac{f_s}{f_0} - 1 \right) \right]} \tag{2}
\]

It can also be shown that if we derive a positive sequence signal from balanced three phase signals then the second term of 2 can be canceled out the frequency response is given by 3

\[
\hat{X}_1 = e^{j\phi} e^{j\pi(\frac{1}{f_0} - 1)} \frac{\text{sinc} \left[ \pi \left( \frac{f_s}{f_0} - 1 \right) \right]}{\text{sinc} \left[ \pi \left( \frac{f_s}{f_0} + 1 \right) \right]} \tag{3}
\]

Of course, if the signal have a single frequency component then it is possible to adjust the sampling frequency \( f_s \) such that \( f_0 \) becomes equal to \( f \), keeping the number of samples in a cycle equal to \( N \). This will eliminate all errors associated with off nominal frequency estimation. But this method of making the sampling frequency and hence sampling time instants dependent on the signal frequency will make them lose synchronism with the Pulse Per Second (PPS) according to the UTC. But if the input signal has combinations of frequencies then it is difficult to get error free phasor measurements even by changing the sampling frequency.

Next, we discuss the out-of-band interfering signals and their filtering, with aim to get accurate phasor measurement.

B. Power System Signal Model

It is important to understand what signals are encountered by the PMU and what is the expected phasor measurement output from the PMU. Bus voltages and currents are affected by several transients and steady state phenomena that distorts their signal away from the pure sinusoidal waveform. To design the signal processing for PMU and ascertain its performance it is required that we develop standard signal input and verify the PMU output against the expected output. Here we develop model for input signal that can be used for the purpose.

A PMU is not expected to respond to the transients decaying in less than one cycle time. Hence the model signal does
not contain the fast transients like lightning and switching transients. The slow transients that range from few cycles to few seconds are considered. These includes the power quality events like voltage sag, swell, decaying DC components, the electromagnetic oscillations caused due to presence of reactors and capacitors in the network and the electromechanical swings.

The transients are evident in the waveforms of the voltage and currents of the system. In general the power system signal can be modeled as combination of various effects, see Fig. 1.

Fig. 1 represents the steady state model where different types of disturbances can be incorporated in addition to the fundamental i.e. nominal signal [12], [13].

A general signal model is expressed as:

\[
x(t) = \Sigma m_h \cos(\omega_i t + \phi_h) + \Sigma m_s \cos(\omega_s t + \phi_s)
+ [1 + \Sigma m_{ai} \cos(\omega_{ai} t + \phi_{ai})] \cos[\omega_0 t + \phi_0 + \Sigma m_{fi} \cos(\omega_{fi} t + \phi_{fi})]
\]

Where terms with subscript \(h\) relates to the additive harmonic signals, the terms with subscript \(s\) relates to additive non harmonic frequency interfering signals, the terms with subscript \(ai\) relates to amplitude modulation signal and the terms with subscript \(fi\) refers to frequency modulation interfering signal. Usually \(\omega_{ai}\) and \(\omega_{fi}\) are equal, but in general they may not be. It is same case with \(\phi_{ai}\) and \(\phi_{fi}\).

C. Phasor Estimation Through DFT analysis of the power system signals

The signal model shown in equation (4) can be further simplified for easy analysis considering just one components of each type of disturbances. By using simple trigonometric identities, it can be shown that an amplitude modulated signal can be decomposed as sum of three components, one is the carrier frequency component with frequency \(\omega_0\) and two side bands with frequencies \((\omega_0 - \omega_{i1})\) and \((\omega_0 + \omega_{i1})\) (5). The amplitude of the side bands is directly proportional on the modulation index \(m_{i1}\). Similarly, the frequency modulation can be decomposed into components with a carrier frequency components with frequency \(\omega_0\) and infinite numbers of side bands with each with frequencies \(\omega_0 \pm k \omega_{fi}\) for \(k = 1, 2, 3, \cdots, \) (6). The amplitude of side bands is proportional to Bessel functions of the first kind with modulating index \(m_{fi}\) as its argument, [14].

\[
x(t) = [1 + m_{ai} \cos(\omega_{ai} t + \phi_{ai})] \cos(\omega_0 t + \phi_0)
= \cos(\omega_0 t + \phi_0) + \frac{m_{ai}}{2} \cos[(\omega_0 + \omega_{ai}) t + \phi_0 + \phi_{ai}]
+ \frac{m_{ai}}{2} \cos[(\omega_0 - \omega_{ai}) t + \phi_0 - \phi_{ai}]
\]

(5)

\[
x(t) = \cos[\omega_0 t + \phi_0 + m_{fi} \cos(\omega_{fi} t + \phi_{fi})]
= \sum_{k=-\infty}^{\infty} J_k(m_{fi}) \cos[(\omega_0 + k \omega_{fi}) t + \phi_0 + k \phi_{fi} + k \frac{\pi}{2}]
\]

(6)

From the above, one point can be noted down from the model that among all types of interfering signals the harmonics, amplitude modulation and frequency modulation frequency components are dependent on the nominal frequency. i.e. if nominal frequency changes the frequency of these components would also change. While the non harmonic additive components remain unaffected by change in nominal frequency.

A discrete Fourier analysis at a resolution of 1 Hz. of a signal as in (4) reveals the different frequency components present in the signal. It can be noticed that the relative amplitude of all off nominal frequency components is quite small. It can also be seen that the amplitude of side bands at frequencies due to frequency modulation \(\omega_0 \pm k \omega_{fi}\) for \(k \geq 2\) is negligibly small. So for both frequency and amplitude modulations the side bands corresponding to frequency \(\omega_0 \pm \omega_i\) is dominant. Where we have taken \(\omega_i\) as common modulation frequency for both amplitude and frequency.

The aim of the phasor estimation is to obtain accurate phasor corresponding to the nominal frequency, as well as accurate frequency estimation of that phasor. When performing the phasor estimation according to (1), the frequency resolution is in multiples of fundamental frequency \(\omega_0\). All the harmonic components of the frequency are easily decimated, but the components corresponding to non harmonic frequency contribute to some errors in the phasor estimation. The contribution of any off nominal frequency component to the phasor estimation at nominal frequency is as per (2) for single phase signal and for balanced three phase signal it is as per (3), with little errors.

We can see graphically from Fig. 2a, that there will be significant attenuation to all off nominal frequencies except the frequencies that are very near to nominal frequency. Usually only the side bands of very low frequency amplitude and frequency modulation signals are within this range. All other frequency components suffer form large attenuation. Also it must be highlighted that the frequency response is not symmetric around the nominal frequency. Hence, a signal having
equal magnitude side bands will have erroneous unbalanced reflections in the estimated phasor. There is in fact some amplification for the frequency component that is slightly higher than the nominal frequency. However, if the signal is symmetric and the positive sequence phasor estimation is performed then as shown in Fig. 2b, the response is symmetric around the nominal frequency and error due to modulation is reflected in a balanced manner.

The above analysis shows that in spite of power system signal being polluted with several off nominal frequencies the phasor estimation through DFT can be quite accurate. Magnitude wise both single phase and positive sequence estimation performs well in case of pure sinusoidal input signal as well in case of polluted signal. While the phase estimation is error free in both single phase and positive sequence estimation if the input signal is pure sinusoidal, but only positive sequence estimation can maintain phase angle accuracy in polluted signal. The error introduced by unbalanced gain of side bands components is reflected in phase angle estimation of single phase estimation.

D. Phasor Reporting Rate and Swing Monitoring

It was mentioned in the development of the signal model that the amplitude and frequency modulation are result of power swings. We have also seen that in nominal frequency phasor estimation the presence of modulations get captured with little error as long as the modulating frequency is low. If the modulating frequency is less than 10 Hz, then the side bands are within ± 20% of the nominal frequency and their phasors measurement is accurate enough to be acceptable i.e. amplitude attenuation is less than 93.5 %. Fortunately the power system inter area and intra area oscillations are much below this range. It is also evident that any other off nominal frequencies cannot be measured accurately. Hence, it is futile to hope that phasor measurements would help in capturing accurately the phenomena that are having frequency higher than 10 Hz.

Usually just the local measurements of the phasor serves limited purpose. It is advantageous to communicate the phasors measurements over long distance and get simultaneous synchronous phasor measurements from different geographic locations. In doing so it is prudent that the quantum of data to be communicated is chosen carefully. It might be possible locally to calculate phasors at rate as high as individual sampling rate i.e. in terms of kHz. However, communicating them at that rate must be justifiable by the applications. If the major application is to monitor power swings it is quite possible that phasor reporting rate be one phasor per cycle, or even lower. Ref. [1], provides standard sampling rates of 10 Hz and 25 Hz for nominal frequency of 50 Hz.

With the limited reporting rate and the fact that swings are reflected in the phasor amplitude and phase angles it is evident that anti aliasing filters are required before the reported phasors are sampled. Any component of the frequency equal to or higher than half the reporting rate has to be attenuated enough so that it does not introduce error in phasor measurement. If not filtered out, the effect of such aliased signal is to introduce phantom swing modes in reported phasors when there is none existing in actual system.

The ref. [1] defines such frequencies as out-of-band frequencies, and requires that the PMU maintain its accuracy in presence of such frequencies. In presence of out-of-band frequency very near to cut off of anti aliasing filter for phasor reporting, the attenuation provided by DFT algorithm for phasor measurement is not enough. It is required that a separate anti aliasing filter is employed with sharp cut off above its pass band to meet the accuracy standards required by [1].

Although it is called anti aliasing filter and has the same purpose, the filter required for eliminating the out-of-band interference is in fact a band pass filter centered around the nominal frequency and having pass band with bandwidth of less than 10 Hz, for the reporting rate of 10 Hz. For the reporting rate of 50 Hz the theoretical lower cut off range of pass band filter can be 25 Hz and the upper cut off range can be 75 Hz. But as the DFT algorithm does not provide enough accuracy in such wide range and any way the swing frequencies are in much lower range, the practical pass band is limited to 35 Hz to 65 Hz.

The frequency response of the filter must be essentially flat in pass band range and having steep cut off range. One example of such filter is the 6th order Butterworth filter with pass band of 35 Hz to 65 Hz. In practice there are other better filters used in commercial PMUs. It is evident that the 6th order Butterworth filter would require a sample train of 13 sample for completely filling its buffers. This will introduce a delay of 13 samples in filtered phasors. In case we take the phasor samples are available at 1000 Hz, then this would mean a delay of 13 ms in obtaining an accurate down sampled phasor estimate. It is also necessary that the phase lag introduced by the filter is corrected before the phasors are reported.

E. Timetags

This correction in phase due to filtering is called group delay compensation. This phase correction would introduce a further time delay in phasor estimation. In [1] the timetag is defined as the time of the theoretical phasor that the estimated phasor represents. The process of choosing the time tag is dependent on the filter applied and its characteristics. If group
delay compensation is not performed carefully then the time tag will be wrong and there would be very large error in the phasor estimation. [1] states that without group delay compensation, as long as input signal frequency is exactly equal to the nominal power system frequency, phase angles will be calculated correctly. However, if the power system frequency is different from its nominal value, the phasors will rotate. While this does represent steady-state condition, it is easy to show that the instantaneous value of the phasor phase angle will be determined by the choice of the timetag and the inherent group delay associated with the actual measurement algorithm.

Figs. 3a and 3b shows the response of the phasor measurement algorithms for unit step change in amplitude and step change of 5 Hz in frequency respectively. It can be observed that even though the plain phasor measurement without the anti aliasing filter has good step response in both amplitude and phase, the filtered output is delayed by quite a time. Reporting these outputs at the actual timetags will introduce gross error and render the phasor measurement useless. Hence it is required that these outputs are timetaged after group delay compensation.

In this case with centered DFT algorithm and 6th degree Butterworth band pass filter and phasor sampling at 1 kHz, we obtain the over all delay of 42 ms. There is further 10 ms delay from instantaneous values as the DFT algorithm is a centered DFT. Hence at any given time there is a delay of 42 ms before the PMU gives out the phasor measured at that timetag. This result would change if a different filter is used.

It can be also observed that use of the group delay compensation, makes the phasor measurement non causal. i.e. In the Figs. 3a and 3b even though the step is applied at time equal to 0 ms. The response in the filtered output with group delay compensation starts at some negative timetags.

Further, it is noticed that in case of amplitude step response the error in phasor measurement persists up to the timetag of around 170 ms. Along with this we have to add the 42 ms for filter delay. Hence the response time of this total system would be around 210 ms. The PMU response time is defined in [1] as the interval of time between the instant the step change is applied and the timetag of the first phasor measurement for which the Total Vector Error (TVE) enters and stays in the specified accuracy zone corresponding to the compliance level (1%).

IV. IMPLICATIONS OF SYNCHROPHASOR MEASUREMENT METHODS

In section III, it was shown that for accurate synchronized phasor measurement it is required that the measurement is done for positive sequence component of the three phase balanced system, and proper anti aliasing filtering is applied before down sampling is done for communication of phasors at rate of one phasor per nominal power frequency cycle. This is absolutely required for meeting the accuracy standards of [1].

This system full fills the requirements of applications like state estimation, and swing detection. Other kind of applications can be model parameter verification like transmission line impedance etc. These kind of applications can be classified into the Wide Area Measurement Systems (WAMS).

The delay introduced by the anti aliasing filter and the band width of measurement of just very low frequency oscillations limits the synchrophasor phasor applications in feed back control. The measurements of synchronized phasor measurements can be used in controlling only inter area oscillations, with controllers having enough controlling power like large HVDC links, very large FACTS devices and generator AVR and governor controls where large number of generators participates. Such applications are classified as Wide Area Control Systems (WACS). Synchronized phasor measurements are not suitable for measuring the faster swings as observed in local mode generation oscillations. This is true even if one removes the anti aliasing filtering and samples the phasors at phasors at faster rate. Hence, synchronized phasor measurement does not look very promising in control applications for local oscillations.

If we have to employ synchronized phasor measurement for
devising newer protection schemes, there are many aspects to be kept in mind. The positive sequence phasor measurements, without the filtering requirements, can still be applied to system protection schemes like voltage instability monitoring and wide area load shedding. The controlled islanding scheme if not dependent on the swing measurements can be made to work faster. Localized protection schemes like supervision of third zone protection schemes, adaptive generator out of step protection and adaptive generator loss of field protection also requires positive sequence phasor measurement without the filtering requirements.

In case of protection schemes like line differential protection, adaptive reclosing etc. it is required that synchronized phasor measurements are available for each phase separately. In such applications it has to be kept in mind that accuracy of 1 % TVE cannot be achieved. This is limitation brought upon by the requirements of speed and phase segregation. Such applications are called Wide are Protection Systems (WAPS).

One more thing that is to be kept in mind is the input sensors like Current Transformer (CT) and Voltage Transformer (VT) for the synchronized phasor measurements. If the purpose of synchronized phasor measurements is for WAMS and WACS, then the measurement range of input sensors is well defined, and near to the rated conditions of voltage and currents. But, if the purpose is for WAPS then it is required that the input sensors are capable of maintaining linear and accurate measurements from range of very low value of current and voltage to high level up to several times the rated limits. At same time the PMU should also be able to handle wide range of the phasor amplitudes. This aspect might put a stringent requirement not only on the PMU but on the complete chain of measurements. Also it is generally not possible for the input sensors used for protection purpose to serve the purpose of measurements as their accuracy is not so high in normal range.

Then, finally there is another aspect of using the wealth of measurement available locally in the substation itself. It is observed that for providing meaningful measurement of state estimation the synchronized phasor measurement is desirable at all lines and buses of a switchyard. Also it can be observed that accurate phasor measurement involves lot of intermediate steps. The data available in the local substation can be utilized for localized state estimation. This is the main theme of [15]. There are several other papers [16], [17], that are modeling the generalized state estimation that works on three phase model of substation.

Other use of the large quantity of synchronized measurements available at substation is to apply data mining techniques for disturbance classification, automatic disturbance report generation, automatic identification of hidden failures of protection systems and extracting knowledge from substation measurements [18], [19].

V. PMU AS DISTRIBUTED SYSTEM

As it was noted the existing PMUs are generally inform of a single physical device and provide the output phasors in compliance with the existing standard. A change in the architecture with adoption of distributed data sampling and distributed utilization of the acquired data will lead to several advantages. The distributed architecture can be explained through Fig. 4. The basic idea is that all analog measurements are converted to synchronized sampled values immediately. All the sampled values are put on process bus as described in IEC 61850 part 9-2 [20]. Different applications tap the data from the process bus as per their requirements and may put their output back to process bus or in the system bus. The PMU acts as one such application.

Traditional PMU can be replicated by accessing the synchronized sampled values of current and voltage through the process bus and then calculating the positive sequence phasors for communicating them to the PDC. In this way only the front end of the PMU i.e. the analog to digital converter is distributed near the actual sensors. This is also the way some of the commercial PMU as moving [4], [6].

The next logical step is to recognize the advantages of having lot of local information available digitally. The most obvious one is having parallel PMUs working on same input data but for different purposes. Here the phasor calculation can be common, but later steps of calculation of positive sequence quantities and rigorous filtering for out-of-band interfering signal elimination can be performed for the output that is going to be used for applications like centralized state estimation and power swing monitoring. The applications requiring phase segregated and faster data can be provided raw output of phasor calculation filters. Moreover, there are possibilities of locally utilizing the synchronized measurements to perform automation tasks, distributed state estimation at substation level and knowledge discovery from the wealth of information available locally. These are possible with a distributed view of PMU.

In summary we define a distributed PMU as a system where phasor measurement is done in several small steps with possibility of data being accessible between stages for various purposes. The stages should be able to be added, modified or removed easily without affecting overall functioning of the
This paper presents some initial ideas about a distributed PMU architecture which might be pursued in detail. It is shown through characteristics of synchronized phasor measurements that positive sequence measurements can be made with high accuracy. However, the stringent anti aliasing filter requirements limit the use of conventional synchronized phasor measurements. For extending its use in controls and protection faster data is required, which requirements are not readily met by the present PMUs. It has been shown that by extending and modularizing the PMU architecture multiple outputs as suitable for various purpose can be obtained, as these outputs anyway form the intermediate steps to get the filtered positive sequence measurements. Finally some of the local applications of the synchronized phasor measurements are discussed.

VI. CONCLUSION

This paper presents some initial ideas about a distributed PMU architecture which might be pursued in detail. It is shown through characteristics of synchronized phasor measurements that positive sequence measurements can be made with high accuracy. However, the stringent anti aliasing filter requirements limit the use of conventional synchronized phasor measurements. For extending its use in controls and protection faster data is required, which requirements are not readily met by the present PMUs. It has been shown that by extending and modularizing the PMU architecture multiple outputs as suitable for various purpose can be obtained, as these outputs anyway form the intermediate steps to get the filtered positive sequence measurements. Finally some of the local applications of the synchronized phasor measurements are discussed.

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