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SECURED MULTICHANNEL SMART GRID MEASUREMENTS UNDER WSN FOR LOW VOLTAGE GRIDS WITH ENHANCED SECURITY

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ABSTRACT

This project deals with smart sensing: a second generation Smart Meters replacing traditional metering device, and the first generation of electronic meters, in order to extract a richer and near real-time information. This information in then transferred on a fast communication network where is needed. In other words, the Smart Meters deployed over the distribution grid create a Sensor Network used for grid control and management via wireless communication instead of traditional power line carrier communication.

The intelligent unit employed in the proposed system is able to communicate using standard metering protocols like DLMS/COSEM, allowing high-level integration with systems that use this information for both billing and customer relationship management. Transient stability simulation studies of large-scalepower systems often generate large amounts of data. This canmake it difficult for power system planners to understand theoverall system response or to identify portions of the systemwith unusual signals. In this project, we present a novel approachthat utilizes communication era, for a secured communication and to make use of available 3G or 4G standards for transmitting the measured data. Hence, this is very advantageous for all the system operators, to share the power line measured data, in order to have a robust control and sufficient power delivery. The geographic visualization of the results is also discussed.Results are demonstrated using the IEEE 118-bus system and a16 000-bus real-world system model.

Index Terms—Clustering, feature extraction, model errors,power system visualization, spark lines, transient stability data.

INTRODUCTION

- There are many views of what is in reality, a smart grid is not a single concept but rather a combination of technologies and methods intended to modernize the existing grid in order to improve flexibility, availability, energy efficiency, and costs.
- Smart Grid 1.0:
- Intelligent meters
- Smart Grid 2.0 (“Energy Internet” enabler):

- advanced autonomous controls,
- distributed energy storage,
- distributed generation, and
- flexible power architectures.
- Distributed generation (DG), flexible power architectures, autonomous controls and loads constitute local low-power grids (micro-grids).
- Still primarily centralized control.
- Limited active distribution network (distributed local generation and storage). Use of virtual storage (demand-response)
- Addition of communication systems
- More efficient loads
- Flexibility issues
- Somewhat more robust

In order to make communication among the plants and other system operators, it is essential to make a rigid measurement. But the nature of the bus, keeps the measured variable in some specific ranges. Hence clustering is performed to make the measured variable unique and to transmit it. Transient stability simulation tools are essential for enabling safe and reliable operations of power systems. In real life large scale systems with thousands of buses, transient stability studies often generate gigantic volumes of data. Thisposes a significant challenge to power system planners to analyze the overall system response and identify portions of the system which might be displaying “abnormal” behavior. An exhaustive analysis being prohibitively inefficient, it is of critical importance to develop methods to automatically extract such informationfrom transient stability data. This paper addresses theabove need by applying clustering techniques on transient stabilitydata, more specifically, voltage and frequency responsesignals. Common features are extracted and outliers characterizedby uncommon features are also identified. Furthermore, avisualization method is presented to infuse geographic informationin the display of the results.

Information extraction from transient stability data is thefirst and most crucial part of this work. It will be shownhow clustering [1] can be applied to identify a set of distinctsignals that characterize the overall system behavior. Groupsof coherent generators [2]–[5] can also be identified in a“model-free” approach. In a prior work [6] we have developeda clustering based methodology to identify groups of generatorsin a 2400-generator system with similar frequency responses toa large fault. While common features of the frequency signalswere identified, outliers characterized by abnormal signalswere intelligently flagged down in two of the generators in thesame process. These abnormalities caused by errors in thesegenerators' exciter models had previously been undetected andwere subsequently corrected. This provided promise of themethodology as an operational tool. However, in this earlierwork, only frequencies were considered which in a stablesystem vary within a narrow range both pre and post disturbance.

Feature extraction from other power system quantitiessuch as bus voltages poses greater challenges and has beenaddressed here. In the previous work, the choice of parametersfor applying clustering techniques was not discussed. Thesehave been addressed in this current paper.The second part of this work focuses on visualization ofthe information extracted from transient stability data, whichis time-varying in nature. Traditionally strip-charts have beenused for this purpose. Such an approach can be quite effectiveprovided one is only interested in showing a few signals.

However, displaying multiple signals on a single plot usingdifferent colors becomes ineffective as the number of colorssurpasses ten [7, p. 125]. In addition, such plots cannot showgeographically distributed information. Wide area frequencyvisualization using animated event replays has been presentedin [8] and [9]. Data collected from frequency disturbancerecorders in a wide area FNET system are displayed withcolored contours for every time step and played in the formof a movie. While certainly useful for some situations, it requirestime to display the animation loop and cannot provideresults at a glance. Again, it is extremely important to displaytime-varying data over a reasonable period as opposed to justshowing the present value and say one time step prior, in orderto convey the variation of signal value over time [10].

Fig. 1(a) and (b) demonstrates how transient stability voltagevariation is often shown for a large system with 16 000 buses.Fig. 1(a) shows the voltage signals at all of the buses over 20 swith a large generation loss contingency occurring at 2 s. Theindividual buses are not identified due to data confidentialityconcerns. Obviously with 16 000 buses the purpose of Fig. 1(a)is not to show the response at any individual location, but ratherto give bounds on the overall system response. Power systemplanners often study the system by looking at a small numberof pre-selected buses. While these locations are chosen withgreat care, they only represent a small sample of the overallvoltage signals. To illustrate, Fig. 1(b) shows the voltage signalsat eleven selected buses spread throughout the system. Notethat by doing so some of the distinct features of the overallsystem response are indeed captured. However, this selection isnot guaranteed to include all of the unique features, especiallywhen these signals may vary depending on the assumed contingency.This failure is illustrated in Fig. 1(c) which shows anabnormal or outlier signal that is absent in Fig. 1(b) and stayshidden in Fig. 1(a). This abnormality could potentially indicateerrors or condition warranting attention.

Another issue is with the visualization shown in Fig. 1(a)–(c).Just by studying the plots, it is not possible to locate where acertain set of signals originates within the geographic footprintof the system. This information can provide important insightsinto the behavior of the system such as identifying weak areasof the system prone to stability issues etc.

The clustering based proposed analysis procedure addressesthese challenges. Important capabilities of this analysis procedureinclude extracting unique signals from the range of signalsexhibited by the complete system based on common features.Similarities between signals are quantified followed bygrouping together similar signals using clustering techniques.Finally a novel visualization technique is presented which embedslocational information with the transient stability signals.

EXISTING SYSTEM

- Electronic meters per each customer (metering layer)
- A Meter Data Concentrator (MDC) per secondary substation, which aggregate data coming from all the customers fed by that substation (concentrator layer);
- A central IT system, the Automatic Metering Management System (AMMS), collecting data from MDCs, (management layer).

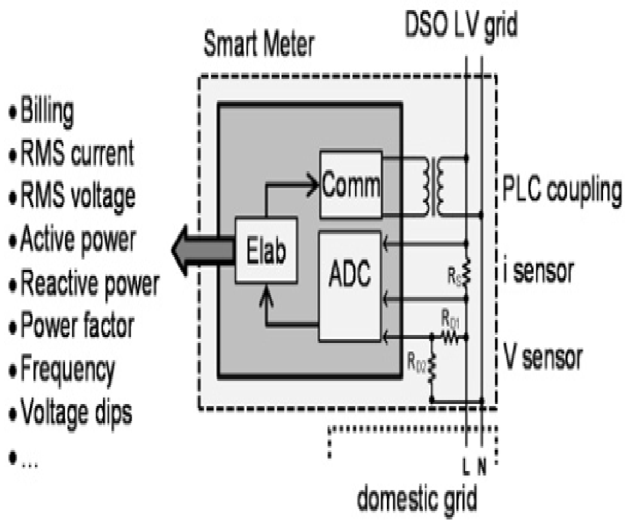

Figure 1: Parameters and PLC coupling

The architecture of an electronic SM is similar to the architecture of an electronic data acquisition system: sensors, the sensor conditioning stage, the data acquisition block (ADC), an elaboration block (Elab) and a communication stage (Comm). The simplified block diagram of a single phase SM is shown in Fig. 2.

The sensors stage is composed of voltage and current sensors, which are directly connected to the LV grid. In LV application, resistive voltage divider sensors are used to acquire the voltage from the grid. Resistive voltage divider sensors use a voltage divider to scale down the voltage of the grid so that it can be acquired by the ADC block of the SM. These sensors offer the best comprise between the cost and measurement performance (good accuracy and linearity). Considering the current sensors, several solutions are available in literature.

Resistive shunts are the cheapest, and the most commonly used solution for residential and LV applications. Shunt sensors use a low-value resistor to produce a low-voltage drop that can be used to estimate the current. Current Transformers (CTs) represent an alternative to shunt-based sensors in applications requiring higher accuracy, higher current ranges and isolation.

The CT sensors produce a reduced current accurately proportional to the current in the conductor by means of a magnet coupling. An additional solution could be the use of Rogowski coil-based sensor. A Rogowski coil consists of a coil of wire wrapped around the conductor carrying the current. The Rogowski coil sensors are more expensive compared to CTs, but their fast response times, highly linear outputs over large current ranges, electrical isolation, and immunity to electromagnetic interference make them an ideal solution for applications with strict measurement requirements. Traditionally, the elaboration block uses the data provided by current and voltage sensors to estimate the customer power consumption, and then, considering the time of use, the customer billing. It is rather simple to make available additional measurements that can be useful for the grid management, since the elaboration is performed by means of a microprocessor. For this reason, the SMs of the next generation can provide, in addition to billing information, also information about: i) active and reactive power consumption, ii) power factor, iii) RMS voltage and current, iv) line frequency and total harmonic distortion, v) number and the description of voltage dips and short interruptions.

Traditionally, the SMs have not demanding communication requirements since they were designed mainly for billing and customer relationship management (red dashed logic communication in Fig. 1). These requirements can be easily satisfied using PLC communication, like IEC 61334-5-1, offering a limited bandwidth (approximately few kilobit per second). This is no longer valid if the SM should be able to transfer near real-time measurements that are used for grid monitoring and management. In addition, these meters work mainly through a non-standard application protocol. This means that smart meter data can be merged with data from other monitoring system of the distribution utility only in the control center, after they were acquired, transfer to and stored in the AMM. On the contrary, in a sensor network approach, the data provided by the SM should be directly available for the DMS, which supervises the distribution grid (dashed green line in Fig. 1).

The transfer of additional information requires a communication infrastructure able to provide a proper throughput and a limited latency, and an advanced protocol to structure the data and transfer the information efficiently. In the literature, several protocols have been proposed for an efficient communication of SMs, like DLMS/COSEM and IEC 61850. Nevertheless, the most promising standard is nowadays DLMS/COSEM, which has been already used by different suppliers.

PROBLEMS IN EXISTING SYSTEM

While monitoring, encryption has not been done.Present smart meters have been realized in power line carrier communication.In case of wired feedback for control system, interference is likely to occur.Power line communication is useless in grids, because grids consists of transformers which acts as low pass filters to filter out the data.

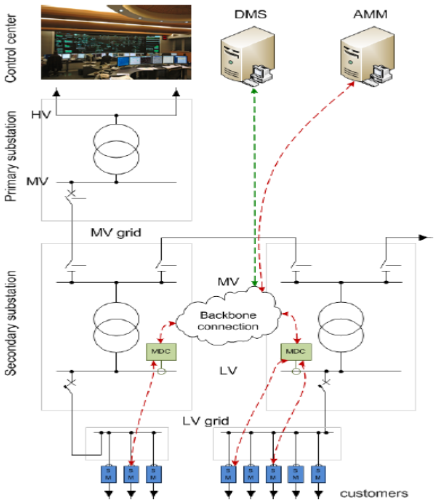

Figure 2. Grid setup and values pick up

PROPOSED SYSTEM

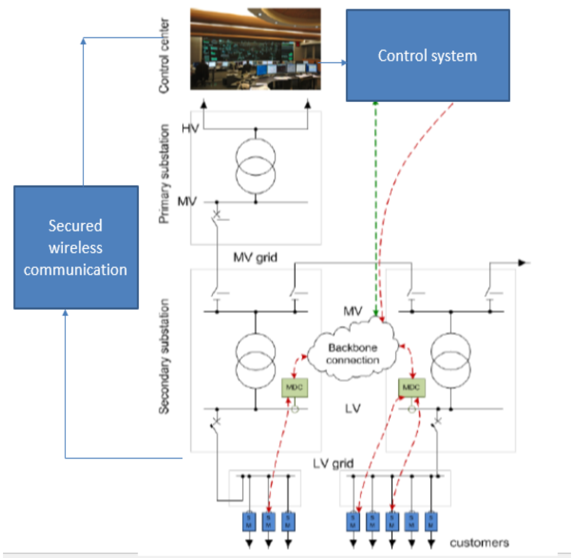

Figure 3: Proposed model

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A communication model for connecting the smart meters is to be designed using a high data rate modulation system with better security.Wireless based measured values can be given to the control section, assuming that the grid and control section is at a distance of 100m. Along with that an encrypted signal is given to the control panel, with speed monitoring and control through wireless sensor networks. Also we prove that the delay introduced by the wireless feedback does not affect the motor speed settling time. Hardware module may designed(optional) using a load for about 100w, with 802.15.4 point to point communication.

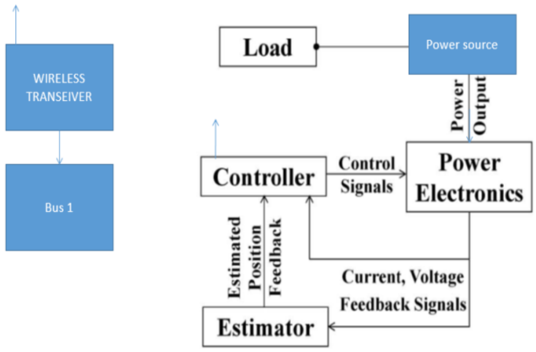

Figure 4. Proposed system with wireless networks

SIMULATION MODEL

The Simulink model shows the power generation using non-renewable energy sources. The power generated is converted into DC and the same is stored in the form of DC in a backup battery. The bidirectional DC-DC converter allows the power flow in both the directions. Hence, either Ac grid or DC grid would get power based the power demand and the availability. The measurements are carried out in this scenario.

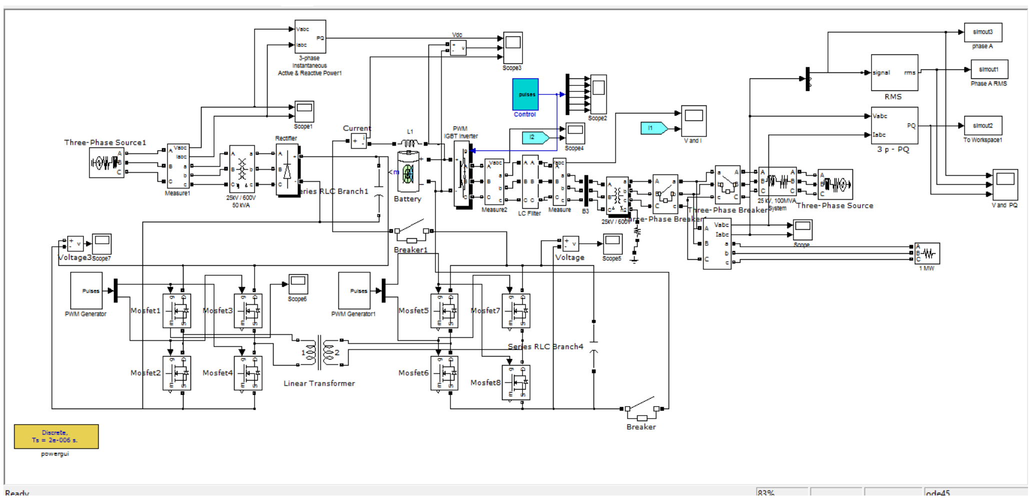

Figure 5: Simulation model

HARDWARE IMPLEMENTATION

TRANSMITTER SECTION

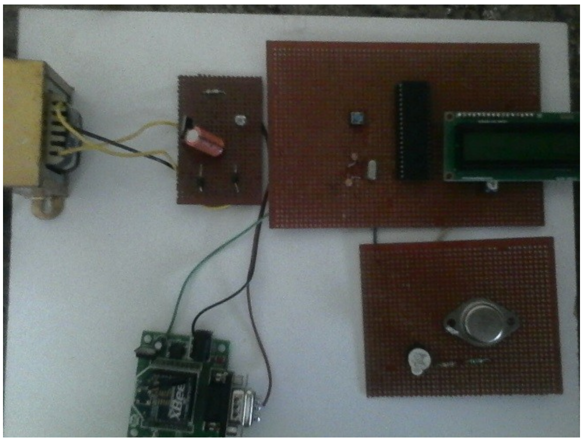

Figure 6: Transmitter section

RECEIVER SECTION

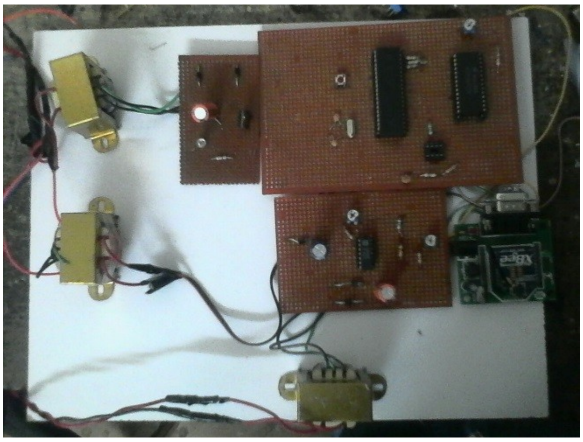

Figure 7. Receiver section

FUTURE SCOPES

1. The project can be extended with additional security with some enhanced encryptions methods such as AES (Advanced Encryption system) .
2. Further, different high end modulations such as above 16QAM (quadrature amplitude modulation) can be used.

3. Hardware implementation of the same could be tried with a short range communication modules such as wifi or zigbee based private networks.
4. Certain simple and efficient methods of harmonics detection can also be integrated with this module.

CONCLUSION

The increasing penetration of small distributed energy resources, like residential photovoltaic panels, in combination with an expected increase of electric vehicles and relative charging stations is causing severe management issues to the distribution grid. Traditionally, the MV/LV substations are not equipped with dedicated instruments that can support the management and the monitoring of the MV and LV grid. The deployment of dedicated instruments in connection point of the distribution grid is not feasible both for technical as well cost reasons. In the paper, the possibility to use the network of SMs as a sensors network for the grid monitoring has been explored and validated through a dedicated experimental set-up. In fact, SMs of the next generation, compared to devices already installed in some countries provide several parameters, like active and reactive power, line frequency, voltage dips and total harmonic distortion, which can be used by DSO to monitor the status of the network. Each SM is connected to the MDC by means of a performing broadband power line communication network. The results of the monitoring, performed over 2 months, highlight the potential capabilities of a large scale monitoring system based on the use of a network of second generation SMs. Using the SM network has been verified that the voltage is below the 5 % of the nominal value only the 3 % of the time in section of the distribution grid under analysis, despite the large presence of distributed energy resources. In addition, the SMs network identifies inversion of the energy flow in part of the distribution grid due to an excess of PV energy production compared to customers consumption.

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