# Distribution Automation and AMI Systems Convergence: an Conceptual Analysis& Case Study

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***Abstract*—Distribution Automation (DA) system comprising of Relays, Reclosers, Auto-Sectionalizing switches, Voltage regulators, Capacitor banks, Fault sensors etc., wastraditionallybeing operated for improving reliability and performance of distribution network with major applications include Fault location Identification, Isolation & Service Restoration (FLIISR), Feeder Reconfiguration (FR) and Integrated Volt-Var Control (IVVC). Due to the lack of omnipresent communication network, across the LV distribution grid many automation functions faced obstacles in terms ofeffective operation. In order to overcome these barriers distribution utilities are eyeing on Advanced Metering Infrastructure (AMI) which creates a communication access to every monitoring and control service point in the distribution grid. With the synergistic benefits that AMI can bring in, power distribution system will be able to realize new functionalities and operational benefits by converging or combining the AMI system with the traditional DA system. In order to effectively integrate these two systems, base analysis and thought process needs to be analyzed. In this paper we propose &analyze the operation of DA & AMI systems based on control-feedback mechanism along with a case study on FLIISR.**

***Keywords—Distribution Automation, AMI, Convergence, System, Control, Feedback, Communication, Network, Distribution*.**

## I. INTRODUCTION

SMART grid [1, 2] incorporates communication and IT technologies in order to achieve advanced monitoring and control of the power grid. Enhanced capabilities of smart grid can significantly improve the reliability, performance and operational efficiency of the distribution system by providing,

1)Communication and metering infrastructure,creatingaccess to the real-time information until the edge of the network for demand side control.

2)Self-healing mechanisms that help grid in automatically recovering from major faults and disturbances upon occurrence.

3)Providing quality power across the grid by automatic control of voltage and power levels.

4)Advanced monitoring infrastructure for gathering accurate data and information.

5)Incorporating innovative smart grid technologies for improving situational awareness.Maintain interoperability across the grid through standardization and automation.

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Analyzingthe above mentioned smart grid capabilities, it can be stated thatautomation systems play a critical role [3] in realizing them. In order to handle power distribution systemwhich has grown multifold in its complexity over the past few years,majority of the smart distribution grid functionsbased on automation technologies were being deployed of which DA and AMI systems are the major platforms [4, 5].Distribution Automation (DA) System as shown in Fig. 1 is a family of technologies that includes control, monitoring, switching, communications and associated intelligence in the form of software applied in the distribution power system typically at the feeder level. DA emerged in the early 1970's to promote computer based techniques for resilient operation of power distribution systems. DA promises utility and customers to reduce operational & maintenance costs, improved power quality & reliability, deferring capacity expansion and enabling new technologies [6, 7]. DA's major automation applications are Fault Location, Identification Isolation and Service Restoration (FLIISR), Feeder Reconfiguration (FR), Integrated Volt-Var Control (IVVC).

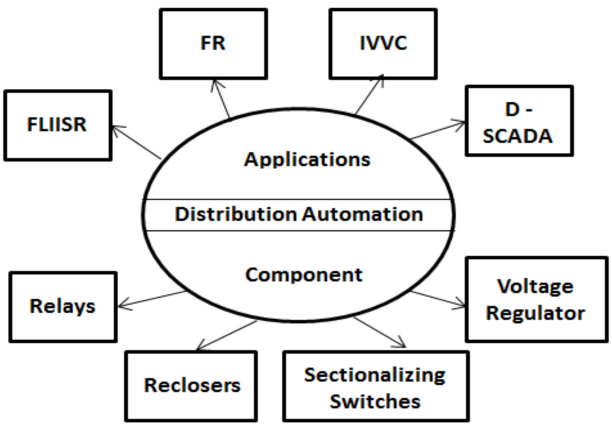


Fig. 1 Distribution Automation System

AMI system deployment, shown in Fig. 2, creates a system wide communication network to monitor and control every service point until the edge of the network [8]. Utilities can gather more real-time information in short time intervals,leading to a wide variety of operational benefits and distribution system management. AMI communications infrastructure will link various TCP/IP based devices across the distribution grid via battery backed-up access points for continuous operation & service, as well as to enable IEEE 802.11 connectivity of the AMI mesh to every monitoring and control points. AMI systems act as eyes through the low voltage distribution system [8, 9]. AMI's major applications are Data Acquisition, Network Management System (NMS), Outage Management System (OMS), Load Control, and Meter Data Management System (MDMS).

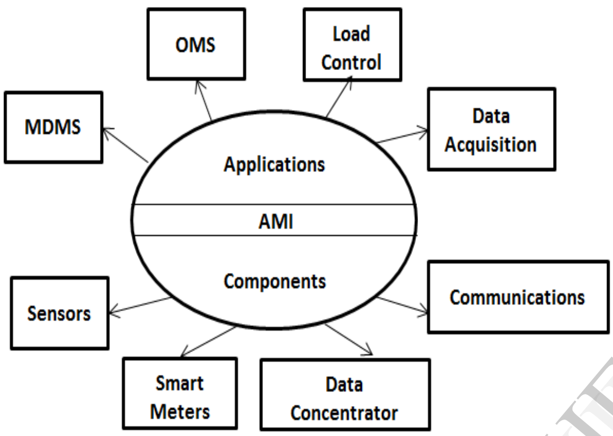


Fig.2AMI System

In order to improve and propose newautomation algorithms for distribution grid modernization further, a need has arrived for convergence of DA and AMI systems in future that has not been explored previously [6, 9].

In this paper, we propose a methodology for DA & AMI convergence based on state of the art technologies, a novel algorithm has been developed for service restoration (part of DA's FLIISR application) based on proposed methodology along with a case study on standard RBTS test system. Further this paper is organized as section 2 emphasizes need for DA-AMI convergence& prior-art, section 3 discusses approach ofDA-AMI convergence, section 4 provides an overview of proposed DA's FLIISRenhanced algorithm based on the convergence approach, section 5discussesconceptual case study on standard RBTS test system,section 6 talks about handling AMI communication delay, section 7 states benefits of proposed approach and section 8 provides conclusion followed by future scope in section 9.

## II. NEED FOR DA-AMI CONVERGENCE

DA operates today at feeder level and has lack of downstream LV distribution network information. AMI system deployment is creating a system wide communications to monitor and control every service point until the edge of the network. Hence convergence of these two systems as depicted in Fig. 3, will justify in doing research on creating possibilities for new and enhanced DA capabilities aiming effective operation of distribution system [10, 11, 12].

In literature very limited amount of work has been reported yet on this topic,where Solomon et al [13] proposed a method of SCADA based Distribution Automation using AMI, solving the problems associated with the demerits of the present method of billing& improving operational efficiency.Michael Thesing [14] has proposed a solution for integrating meter data with separate DA applications and detailed the requirements & analysis of Volt-Var optimization. M/s Elster [15] has leveraged the DA &AMI systems for implementing Conservation Voltage Reduction (CVR) technology, which is considered today as the first application of DA-AMI convergence. DA & AMI features are captured in Table I.

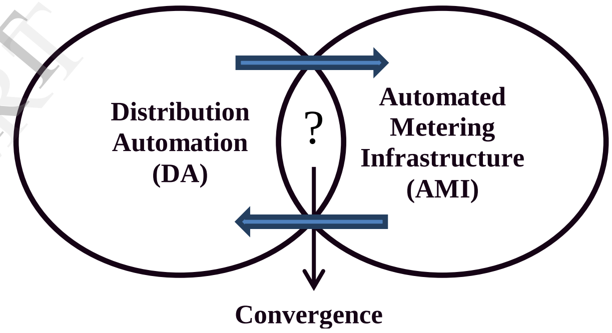


Fig.3 DA& AMI Convergence

Why DA-AMI Convergence?

1)Distribution Automation System today have little or poor visibility outside of the distribution substation& feeder and down to the customer level.

2) AMI systems deployment creates a system-wide communications network to every service point on the utility grid – "but"has limited applications and benefits than expected.

3) DA-AMI convergence will provide unprecedented opportunities for distribution grid modernization that have notbeen fully explored previously, improving DA visibility and increasing AMI applications.

4)DA applications can have access to real time data until the edge of the network and can analyse & perform protection, automation& control based on near real-time conditions in distribution system with greater resolution.

5) Utilities can achieve better control in maintaining reliability & quality indices as per the regulatory requirements.

TABLE I
DAAND AMI FEATURES

| | DA | AMI |
|---|---|---|
| **Characteristics** | Control/Analyze | Measure/Respond |
| **Operation** | Feeder | Distributor |
| **Applications** | FLIISR, FR, IVVR | Load/Peak Management |
| **System** | DMS, D-SCADA | MDMS, OMS, NMS |
| **Primary Devices** | Relays, Reclosers, Switches | Smart Meters, Routers |
| **Voltage Level** | 33/11KV | 400/230 V |

## III. PROPOSED DA-AMICONVERGENCEAPPROACH

Based on the requirement, characteristics, components and applications of DA and AMI systems mentioned in section 1 &2, we propose following closed loop control operation,whereinDA acts as a controller and AMI acts as a feedback system for Power Distribution System Operation (≤ 33 kV level) as shown in Fig. 4.

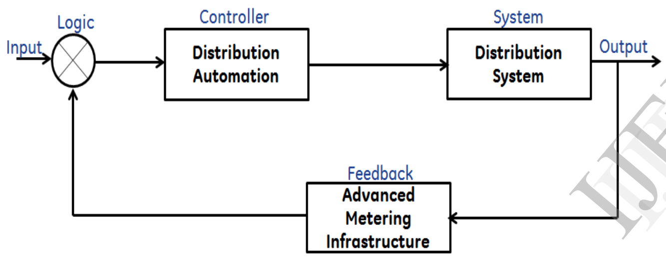


Fig. 4 DA-AMI Convergence System

Further as depicted through Fig. 5, DA system consists dozens of automation algorithms or logics which performspecific controlactions based on predefined conditions&monitoring various set parameters. Automation Function executes the control algorithm on distribution system in order to realize the action definedin DA system when predefined conditionsare satisfied. AMI captures response from the distribution system at required or specified monitoring points against the control action executed by DA. AMI sends the feedback captured to DA system, within the pre-defined time interval, as per the control algorithm requirement. DA analyzes the effect of control algorithm based on feedback data and performs any corrections for network violations, if required instantly. Additionally the feedback data can be used for continuous monitoring of the various set parameters.

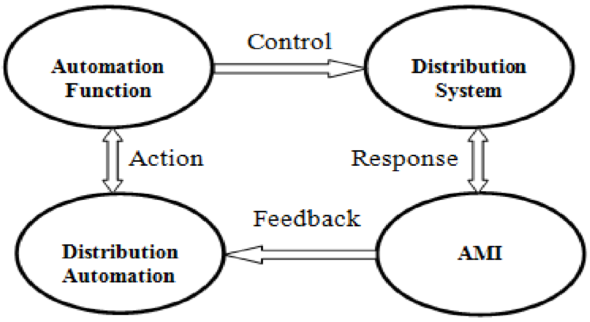


Fig. 5 DA-AMI Convergence Approach

In the nut shell, DA system requires feedback from AMI system with response time depending on the dynamic nature of automation algorithm [6]. Hence information should flow from selected points in AMI to DA critical or non-critical feedback data defined in terms of priority of messages to reach DA system at required latency as shown in Fig. 6.

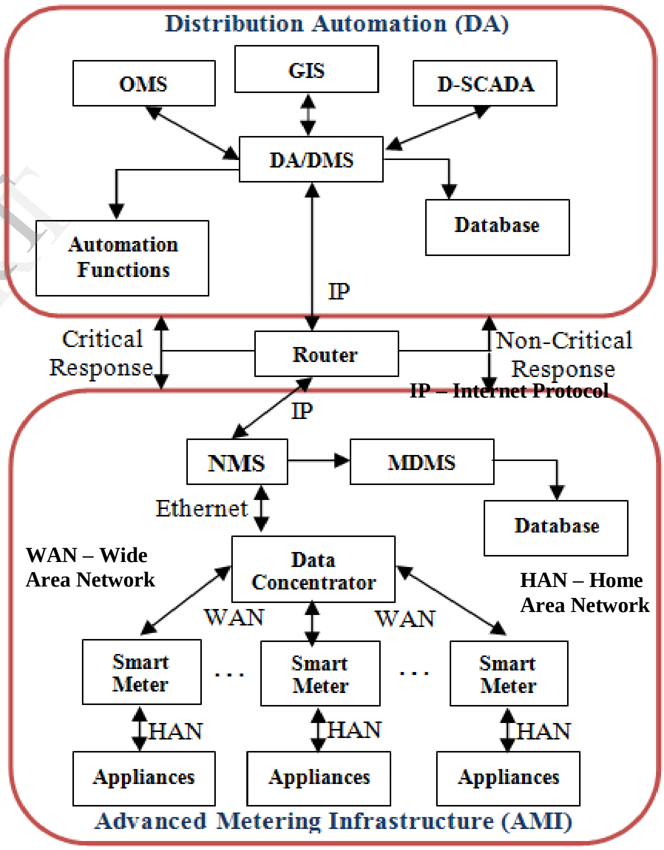


Fig. 6 DASystem to AMI System Information Flow

Where,

MDMS – Meter Data Management System

NMS – Network Management System

OMS – Outage Management System

GIS – Geographical Information System

Research work on in-depth analysis of communication architectures, protocols, latency, selective meter data and data framessynchronization, reporting ratesas required for DA-AMI systems integrated performance requirement is currently being carried out by authors and would be presented in detail as a separate article.

## IV. DA-AMI CONVERGENCE APPLICATION TO FLIISR

One of the major and critical Distribution Automation application which is widely used in today's distribution system operation is Fault Location Identification Isolation and Service Restoration (FLIISR), which helps in improving distribution system reliability by automatic fault mitigation.

In the current distribution system with the increase in complexity and load, faults occur very frequently and its clearance and restoration has gained a lot of importance in recent times due to the stringent reliability requirements [16]. Although temporary faults like insulator flash-over due to lightning can be addressed easily by using Reclosers and service can be restored easily to all the customers, permanent faults require actions by relays that operate auto-sectionalizing and tie-switches to de-energize faulted sections around the substation or feeder and restore power to remaining sections as quickly as possible maintainingreliability [17].With respect to analysis done in section 3, DA's FLIISR function takes action when fault occurs, controls switches to restore power to healthy network, AMI captures distribution system response for network violations if any and sends feedback to DA system. The operation of FLIISR algorithm based on DA-AMI convergence approach as shown in Fig. 7 is enhanced and proposed as explained below in order to improve the effectiveness of existing FLIISR algorithm.

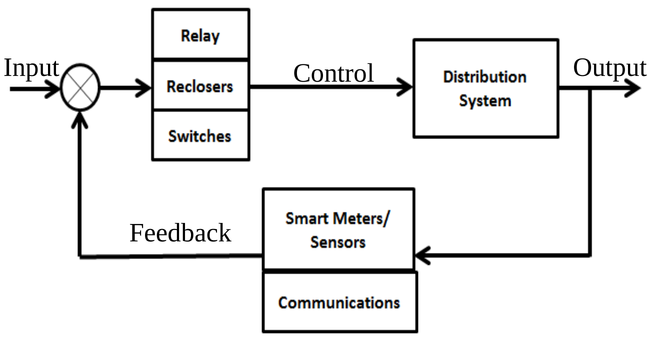


Fig.7 FLIISR operation on DA-AMI Convergence System

### 4.1 FLIISR Algorithm Based On DA-AMI Convergence Method:

1) Execute Phase Identification algorithm [18, 19] to map connectivity of [Meters→Phase→Transformer].

2) Each load point [Meters→Phase→Transformer] in Distribution System is represented or configured as a "Segment".A "Load Segment" is defined as a part of network which represents 3-phase distribution transformer (11kV/400V) and its associated downstream LV 3-phase 4-wire distribution system.

3) A mapping of devices considering normal operation of system shall be done from, Segment →Feeder Branch →Auto-Sectionalizing Switch→Circuit Breaker→11 kV Bus→33 kV Bus, based on the network topology of distribution system and using unique GIS asset ID tags [20] (16 or 32-bit integer format) of these distribution system components stored in GIS system database.

4) For all possible predefined fault restoration schemes evaluated during offline study based on fault location and switching options, new mapping of devices shall be done from,Segment→Feeder Branch→ Auto-Sectionalizing Switch→Tie-Switch→ Circuit Breaker →11 kV Bus→33 kV Bus, as mentioned in step 3 and stored in system database.

5) When a fault occurs and the corresponding circuit breaker is tripped, Auto-Sectionalizing (Normally Closed) Switches operate as per step 4, based on the fault location identified to isolate the faulted network.

6) Over current protection settings for feeder branch circuit breaker through which power needs to be restored to additional loads effected by fault, iscomputed adaptively based on last AMI feedback load data monitored from 3-phase distribution transformer meters in each load segment connected to feeder branch prior to fault and additional load segment's added to branch after fault being isolated, and as per network mapping defined in steps 3 & 4.

7) A set of Auto-Sectionalizing and Tie Switches (Normally Open) operate based on predefined fault restoration schemes as mentioned in step 4 in order to restore the power to remaining part of the network which is not affected by fault, through network reconfiguration.

8) During the start of time duration (say T), after service restored and before the fault is cleared permanentlyby field crew, first feedback message shall be taken using AMI system within 1 minute from all the segments which are restored after fault, in the form of limited snapshot data of the required 3-phase & 1-phase smart meters collected by Network Management System (NMS) based on the pre-defined mapping as defined in step 4, to ensure that power is restored successfully to all possible customers without any discrepancy in service restoration.

9) Based on the continuous AMI feedback mechanism from each segment, possible immediate effects of service restoration such as, circuit or branch

overload; operational constraints, phase unbalance and voltage limit violations at weak points in the system are analyzed and controlled during fault restoration duration (T)in each segment due to dynamic load variation characteristic of distribution systems. Voltage control through IVVC, load curtailment through load control relays in smart meters on a particular segment's phase needs to be executed during theduration 'T' in order to mitigate the possible restoration problems effectively or immediately using AMI feedback.

## V. CONCEPTUAL CASE STUDY ON RBTS TEST SYSTEM

In the above sections we discussed the convergence of DA and AMI systems and proposed algorithm for enhancing existing FLIISR application. In this section we focus on implementation aspects of DA-AMI convergence system for enhancing the FLIISR operation[21] through a conceptual study on RBTS (Roy Billinton Test System) 33 KV distribution system at bus 2 [22]. This system as shown in Fig.8has 2 tie switches, 14 sectionalizing switches, 22 load points, 4 Feeders, 22 transformers and 6 circuit breakers. Numbers 9, 11, 13, 15, 17, 19, 21, 22, 23, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, and 58 represents the distribution transformer load points or segments. Switch locations 5 and 28 represents tie-switches.

Given the background of load data and network diagram of the RBTS test system, the present section discusses the implementation aspects of enhanced FLIISR algorithm on RBTS test system considering a fault at point "F" in the network and based on DA-AMI convergence approach discussed in section 3 & algorithm steps in section 4.

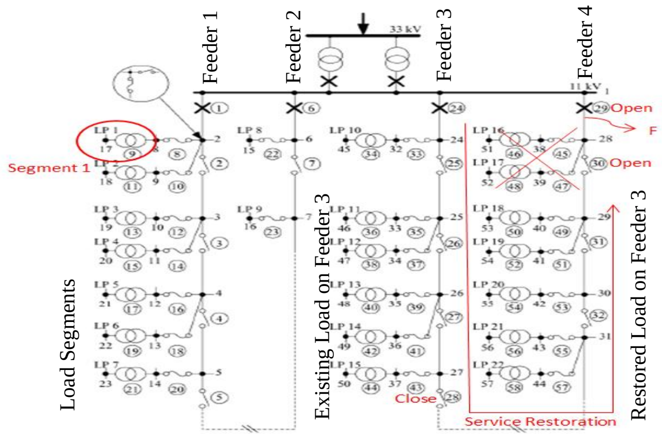

Fig.8 Roy Billinton Test System with 22 load segments

### A. Distribution Network Mapping:

*A.1*Phase Identification Algorithm needs to be executed at each Load Point (LP) in order to map all the single phase meters connected to its respective supply phase and transformer from which supply is provided. For example consider a Load Point shown in Fig.9, phase identification needs to be done for all single phase meters connected to transformer location points B, C, and D in order to map all the meters connection to its respective phases (R, Y & B) and transformers at locations B, C, D from which supply is provided and to 3-phase transformer at location A. This needs to be repeated for all the remaining load points where single phase meters are connected.

*A.2*The mapping "[Meters→Phase→Transformer]" done for all load points are configured as segment's and stored in system database. A "Load Segment" is defined as a part of network which represents 3-phase distribution transformer (11kV/400V) and its associated downstream LV 3-phase 4-wire distribution system.

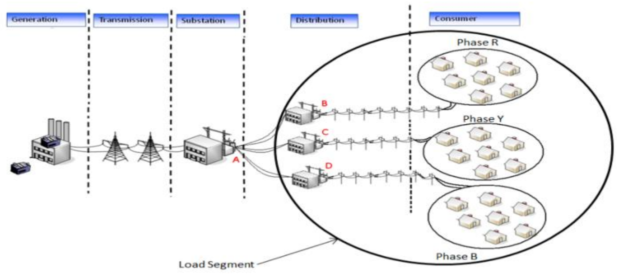

Fig. 9 A typical load segment of residential type (Ex: LP1 in RBTS)

*A.3*Each segment will be mapped to its corresponding upstream network components, based on the unique 16 or 32 bit asset ID tagsof each distribution component and stored in system database as per network topology, for example consider segments 1,3,11 & 19 in Fig. 6 can be mapped as, (asset ID tags are shown in brackets)

[Segment 1(32892)→Feeder 1(38722)→ Circuit Breaker 1(57238)→ 11 kV Bus 1 (26385)→ 33 kV bus (56327)]

[Segment 3 (48399)→Feeder 1(38722) → Circuit Breaker 1(57238) → 11 kV Bus 1 (26385) → 33 kV bus (56327)]

[Segment 11 (86128)→ Feeder 3 (51678)→ Auto-Sectionalizing Switch 25 (98613)→ Circuit Breaker 24 (67162)→11 kV Bus 1 (26385) → 33 kV bus (56327)]

[Segment 19 (38799)→ Feeder 4 (64818)→ Auto-Sectionalizing Switch 30 (15767)→ Circuit Breaker 29(08126) →11 kV Bus 1 (26385) → 33 kV bus (56327)]

*A.4*When a fault occurs at point 'F' as shown in Fig. 8, Circuit Breaker 29 will trip to clear the fault. Based on the fault location identified, Auto-Sectionalizing Switch 30 will be opened in order to isolate the faulted sections which are segments 16 & 17. Power shall be restored to segments 18, 19, 20, 21 and 22 from feeder branch3 which are affected by fault, closing the tie-switch 28.

*A.5*Based on the reconfigured or modified network, each segment affected by fault will be re-mapped to its new corresponding upstream circuit elements automatically based on the pre-analysis performed based on location of fault and possible switching action, in order to restore power after each fault. For example consider power to segments 18 & 22 restored from feeder branch 3 using tie-switch 28for a fault at point 'F' in Fig. 6,these segments are re-mapped as shown below,

[Segment 18 (98437)→ Feeder 3(51678) → Auto-Sectionalizing Switch 31 (07966)→ Tie-Switch 28 (12345)→ Circuit Breaker 24 (67162) → 11 kV Bus 1 (26385) → 33 kV bus (56327)]

[Segment 22 (81648)→ Feeder 3 (51678)→ Tie-Switch 28 (12345)→ Auto-Sectionalizing Switch27 (98718)→ Circuit Breaker 24 (67162) → 11 kV Bus 1 (26385) → 33 kV bus (56327)]

B. Analysis in Performing Service Restoration:

During the time duration (T), after Service is restored to healthy part of the network and before fault is cleared permanently by field crew to affect normal network conditions, the following analysis needs to be done.When the fault occurred at point "F", fault needs to beisolated by disconnecting segments 16 & 17 connected to feederbranch 4 and restoring segments 18, 19, 20, 21 and 22 by connecting to feeder branch 3 using tie-switch 28. Assuming that RBTS test system is operating on specified load data [22] (which in real case is practically measured by AMI smart meters from each segment and sent as feedback to DA) as shown in Table II for analysis purpose,

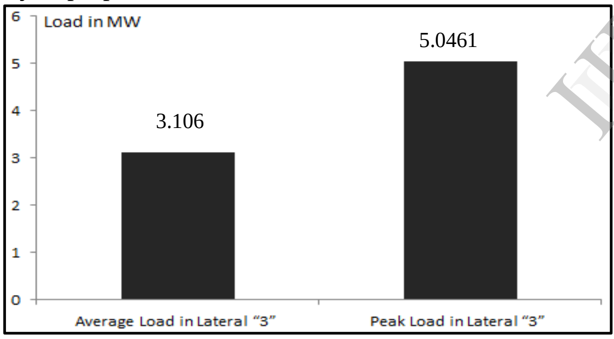


Fig. 10 Loading on Feeder '3' before Fault occur

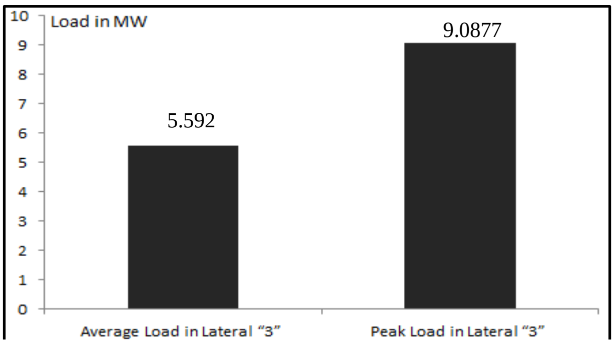


Fig. 11 Loading on Feeder '3' after Fault occur and Power Restored through Feeder '3'

Considering that fault can occur at average or peak loading condition, from Fig. 10 & 11, it can be concluded that,

- ✓ % Increase in Average Load = (5.592-3.106)/3.106 = 80.
- ✓ % Increase in Peak Load = (9.0877 – 5.0461)/5.0461 = 80.
- ✓ Number of customers affected from fault = 10 commercial + 200 Residential.

Hence during the time durationT, when the network is re-configured and before the fault is cleared by crew, we need to ensure following conditions in network which are considered as aims of effective restoration schemes [22],

1) Restore as many loads as possible.
2) No violations in engineering or operational parameters.
3) Power balancing should be maintained or performed.
4) Restoration to be done in short time possible.
5) Maintain radial network structure.
6) No overloading conditions of any network component.
7) Additional conditions,if any, as stated or required specific to distribution utility.

TABLE II
LOAD DATA OF RBTS TEST SYSTEM

| **No. of LP's** | **Segments (LP)** | **Load Type** | **Avg. Load in MW** | **Peak Load in MW** | **No. of customers per LP** |
|---|---|---|---|---|---|
| 5 | 1,2,3,10,11 | Residential | 0.535 | 0.8668 | 210 |
| 4 | 12,17,18,19 | Residential | 0.45 | 0.7291 | 200 |
| 1 | 8 | Small Industrial | 1 | 1.6279 | 1 |
| 1 | 9 | Small Industrial | 1.15 | 1.8721 | 1 |
| 6 | 4,5,13,14,20,21 | Government | 0.566 | 0.9167 | 1 |
| 5 | 6,7,15,16,22 | Commercial | 0.454 | 0.75 | 10 |

C. Considerations from Analysis Data:

The following are the possible effects to consider, not limited to, which can occur during period T,

*C.1*Number of customers for which power is restored from Feeder 3 = '2 Government + 10 commercial + 400 Residential' with an increase in average and peak load by 80%, indicating the amount of feeder3 overload condition.

*C.2*Phase unbalance can occur in segments 18 & 19 having 400 customers due to the load being consumed diversely in each phase after service restoration by individual single phase residential customers having rated capacity of 3 KW and average load of 2.25 KW per home and due to possible presence of residential micro-grids & unauthorized power theft.

*C.3*Voltage limit violations (+/- 5%) can occur in end of line or weak points in segments 18, 19, 20, 21 and 22 and specifically in segments 18 & 19 which are at the extreme end of reconfigured feeder branch 3.

D. Proposed Remedial Actions Based On AMI Feedback:

The following are the remedial actions that needs to be taken using AMI feedback data,

*D.1*Over current relay trip settings for circuit breaker 24 connected to feeder branch 3 needs to be computed and updated adaptively online to accommodate the extra load added due to service restoration after fault at location "F" in Fig. 6 using near real-time conditions (which would have beennot possible without AMI feedback), based on last successful feedback messages, containing load data, taken using AMI system from all the 3-phase meters connected to distribution transformers in restored segments 18, 19, 20, 21 and 22 prior to fault occurrence, withan additional incremental marginadded to the setting to avoid over load tripping of relay after service restoration, assuming that feeder line's thermal capacity is designed to accommodate additional (load) segments.

*D.2*Based on the first successful feedback messages containing load & voltage data taken from required 3-phase and 1-phase meters in restored segments 18, 19, 20, 21 and 22 using AMI system in the form of limited snapshot data indicating meter powered-up condition, service restoration to all possible segments can be confirmed or validated. The required meters are chosen based on network topology of each segment. In case of any discrepancy with respect to expected AMI feedback, restoration scheme shall be re-analyzed and performed again.

*D.3*Based on continuous feedbackmessages containing load data taken using AMI system from 3-phase meters connected at each distribution transformer at regular intervals of time in segments 18, 19, 20, 21 and 22 after service restoration and during period 'T', phase unbalance indicescan be computed as per standard IEEE or IEC standards convention. In case the phase unbalance index goes beyond specified limitsconfigured by utility, Priority based load curtailment using 40A and 2A load control relays installed in single phase meters can be performed for each phase to maintain balance within the specified limits.

*D.4*Based on the continuous feedback messages containing voltage datataken using AMI system from single phase meters (connected at pre-identified weak points in system) after service restoration and during period 'T', voltage deviations [4] occurred in segments 18, 19, 20, 21 and 22 shall be corrected by controlling voltage regulators and/or capacitor banks connected to individual (load) segments.

## VI. HANDLING AMI COMMUNICATION DELAY

When AMI acts as feedback to DA system, it needs to send required feedback messages as a critical or non-critical response based on dynamic control nature of DA algorithms. For example FLIISR and IVVC algorithms are dynamic (online) in nature and requires feedback within few ms after control or execution of algorithm which can be considered as critical response, whereas Feeder Reconfiguration using AMI data is an offline study and requires feedback within a regular interval of 15 minutes which can be considered as non-critical response. Network Management System (NMS) application in AMI can act as interface to DA as shown in Fig.12.

Due to the current advancements in communication routing techniques and IP technology with AMI slowly being migrated to IP based communications [23], it is possible to send messages within a few milli-seconds of time over Widea Area Network (WAN) communications without significant delay, which is already proven across many smart grid applications [24]. Advanced Smart meters in AMI supporting IP differentiated services [25, 26] like Quality of Service (QoS), Priority tagging and Differentiated Services Code Point (DSCP) and communication router's at NMS & DA network interfaces supporting advanced routing techniques [27] like VLAN, IGMP v3, ICMP, IP Multicast etc., definitely promises DA-AMI systems to integrate seamlessly and work together in a synchronized manner as per the stated requirements. Measuring communication delay& latencies is out of scope this article.

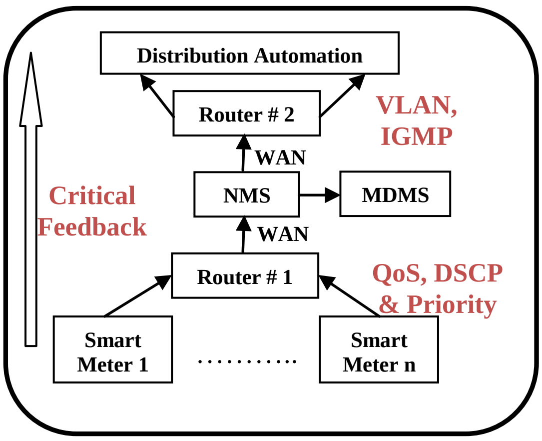


Fig.12 DA-AMI System's Communication

## VII. BENEFITS OF PROPOSEDCONVERGENCE APPROACH

In the literature [21, 28-35] significant amount of work has been reported in performing power restoration analysis after fault. All these methods depend on either simulated load flow data or short term load forecast look-ahead analysisdata for defining fault restoration schemes and analyzing network violations at feeder level considering various fault locations, based on offline analysis. Though these methods were successful to an extent, none of these methods provide a mechanism to restore the power based on near real-time conditions in network before fault occur and validate network violations, if any, post restoration until the edge of each load segment. Proposed DA-AMI Convergence approach provides a higher resolution and accurate method of power restoration by providing last mile AMI feedback (before restoration) for restoring power based on near real-time conditions and first mile/continuous AMI feedback (after restoration) to avoid network conditions violation with respect to restoration aims defined in section 5.2. Reliability Indices like System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI) can be maintained better with respect to regulatory requirements and would definitely help utilities to avoid additional penalty costs using this approach. It should be noted that DA-AMI Convergence does not affect performance or time of restoration rather provides an effective restoration analysis prior and post to fault occurrence.

## VIII. CONCLUSION

Distribution Automation traditionally been operated on legacy distribution systems in order to increase reliability, efficiency and performance will foresee more benefits in the future due to its integration with the AMI system providing unprecedented opportunities for power grid modernization. On the other hand AMI being the first initiative [36] taken by most of utilities as part of their smart grid road map will provide system wide observational capabilities operating in convergence with the Distribution Automation system. The information collected from the AMI system supporting required latency, bandwidth and speed of response [37], acting as feedback to Distribution Automation applications will enhance its functionality multifold and drives better grid operation and efficiency. DA- AMI convergence platform will not only enhance existing DA applications but also provides a unique platform for incorporating additional automation applications in the distribution system which faced obstacles in practical realization earlier. As DA & AMI systems are operating independently today, converging or integrating these two systems would be definitely considered by various distribution utilities based on our preliminary analysis.

## IX. FUTURE OPPORTUNITIES

Having analyzed that DA-AMI convergence provides benefit for utilities, a standardized method of integrating and operating these two systems in coherent manner is required. New automation functions can be researched for modernizing the distribution grid based on the convergence thought process.

## X. ACKNOWLEDGMENT

The authors would like to thank M/s.GE Energy Management, HTC and Mr. John D. McDonald, Director of technical strategy & policy development, Digital Energy and Past President of IEEE PES, for the technical support, encouragement and guidance in writing this article.



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