Abstract: The static world with a closed control room within the utility industry is changing to an environment where the SCADA/EMS/DMS system is part of the corporate IT systems. The driving force for this is the need for utilities to have accurate data available for quick business decisions on a deregulated market. Cost reduction and quality improvement facilitated by increased information exchange is a strong incentive for utilities to require open system enabling integration. Constantly changing requirements force the utility industry to establish communication between new combinations of systems and changing sets of applications within a system. This results in new requirements on flexibility and openness for systems and applications. To meet these new requirements the solutions from the SCADA/EMS/DMS vendors is to adopt new technology that makes the systems more flexible and enable sharing of information in a fast and efficient way. This paper discusses the general requirements and trends and new SCADA/EMS/DMS solutions that will meet the customer requirements and aspects on delivery and system upgrades.

Keywords: SCADA, EMS, DMS, deregulation, flexibility, openness, component technology, API, information model, standards.

I. BACKGROUND

Market

Deregulation

The environment the utility industry is facing is changing rapidly with deregulation that sweeps over the world. Even if the deregulation rules looks different in the different parts of the world there are some basic things that are common.

Changing enterprise structures

Utilities are divided into different companies, e.g. grid operation, network services and market operations. Acquisitions and mergers between companies to enable a size that makes them competitive on the market have become common. The mergers are not only domestic so some companies will act as global players. The total number of utilities will decrease. The division of the utilities opens up for new participants that have not previously been involved in the utility business. This is mostly seen in the trading with electricity and in the retail business. Traditional energy providers like gas companies is also selling electricity to their customers. To be competitive they extend their offers to include more services than only delivery of electricity. This leads to increased focus on the end customer and quality of the electricity supplied. Services without competition like distribution grids will be set under surveillance by authority regulations.

Private investments in power systems are increasing. Increased number of independent power producers is a sign. They are focusing on smaller generation units with short delivery times and fast payback on returned investment. There will also be increased private investments in the power network.

Vertical integration

The changes in the enterprise structure have changed the traditionally horizontal orientation to a vertical. Organisations now reflect particular core activities as network operation and asset management.

Cost reduction at utilities

Competition between the actors on the new market leads to an increased financial pressure within the utilities. New investments will be more judged on financial than on technical terms. Optimised use of existing assets will increase in importance. The operational expenditures will be examined and reduced where possible. Expansion and development will be on the core business.

Fast changing requirements

From the past 100 years when the rules have been "static" for the utilities the requirements are now changing fast. The fast changes will continue over the coming years while the deregulation rules will oscillate to a more stable position. However the pace of the changes will be much higher in the future than it has been in the past. The utilities must have flexible organisations and IT support to be able to quickly react to the changes.

The speed in the change of requirements leads to a requirement on the vendors to have solutions that can be delivered fast and be upgraded to meet new demands.

Increased IT-system integration

The changes in the enterprise structure, changes in the requirements and the need to always have accurate data available will lead to a need of synchronising the information in different IT system. Easy integration of IT system will be a parameter that sometimes will overrun functional demands since integration can secure that data is more consistent between systems. This results in more accurate decisions.

Flexibility and adoption to existing and emerging standards for data and information model exchange will be important requirements on SCADA/EMS/DMS systems.
Optimised use of power system
When the power system investment is reduced there is a demand for new functionality that can optimise the utilisation of the network without decreasing the safety. This will be done through new functions that in real time calculates the actual conditions and safety margins in the network. Another optimisation is to minimise the maintenance and maximise the life of the existing assets. The algorithms that support creation of maintenance schemes will be more and more sophisticated.

Technology
The rapid change for the utility business is not only a change in the business rules but also the possibilities created by the rapid IT development.

Bandwidth from mega to giga
Communication that in the past has been a bottleneck for distributed processes like the electrical is now changing rapidly. With communication speed going from mega to gigabyte and the expansion of the Internet creates new opportunities to exchange data. This will lead to more distributed environments and new protocols for data exchange.

Internet
Internet has become a commodity that everyone get in contact with and this will in few years change the way we expect data to be available. This will change the requirements on the user interface or the accessibility of user interface. Internet and especially the e-businesses will also drive the development for platforms to have high availability, scalability and performance. These are the same characteristics that we traditionally see in SCADA/EMS/DMS systems.

Component technology
To be able to cope with a more complex environment that contains of big IT systems there will be a need to divide the big systems into smaller parts or components. New technologies like COM and CORBA enable this division. The division leads to faster release cycles for every component and the flexibility for the utility to choose components from different vendors. The component based system makes it easier for the utility to build the system incrementally since they can buy the components when the need arise.

SCADA/EMS/DMS will go from a single product to a concept consisting of several different products.

Overview
A SCADA/EMS/DMS exist in a changing environment consisting of other IT-systems, other SCADA/EMS/DMS systems and RTUs, IEDs (Intelligent Electronic Devices) or SCSes (Substation Control Systems). In this environment there are increasing requirements for integration. The web will be of increasing importance as it opens for remote usage and not only access from within a control room or office. A SCADA/EMS/DMS itself will become more flexible enabling upgrade of existing functionality and installation of new functionality.
changes. An API definition language is the basis for such a platform and currently there are two major languages, OMG IDL (Object Management Group [1], Interface Definition Language) and Microsoft IDL (MIDL). Both IDL languages come with middleware, various CORBA ORBs (Common Object Request Broker Architecture, Object Request Broker) for OMG IDL and COM/DCOM (Component Object Model/Distributed Component Object Model [2]) for MIDL. The middleware enable remote interconnections. COM/DCOM has restrictions concerning use with other operating systems than Microsoft Windows while CORBA ORBs in general support various operating systems and computer hardware. CORBA support interoperability between systems by use of the IIOP (Internet Inter Orb Protocol) protocol. As Java RMI (Remote Method Invocation) use IIOP it also provide a bridge between an ORB and the increasingly popular Java environment.

A SCADA/EMS/DMS is typically built on services as a real-time database (RTDB) serving real-time critical software, a relational database (RDBMS) serving non real-time critical software and a messaging system for propagation of changes. Defining standard APIs for these services will also enable portability between different RTDBs, RDBMSes and messaging systems. In Figure 2 the thick line in the centre of the SCADA/EMS/DMS box indicate the platform.

**Application integration**

Applications typically have some local in memory data structures optimised for performance and used by the application logic when running. These data structures are initialised with configuration and input data before execution and results are distributed from it to consumers after execution. Traditional SCADA/EMS/DMS designs use a RTDB and/or a RDBMS to persistently store configuration data inputs and results. The database is traditionally also used to exchange data between applications and it then also becomes the central middleware of such a system. With the introduction of generalised APIs the database will no longer necessarily be the central middleware enabling increased flexibility. Configuration data used by an application can either be specific to the application (of no use to other applications) or general, e.g. the pi-equivalent is specific to the EMS network applications (state estimator and load flow) while power line geometry’s and transformer test protocols are general. Configuration data is typically maintained by a specific DE-tool (Data Engineering tool). Application inputs and results are usually presented to operators in application specific displays but may also be presented by other applications like world map or single line diagram applications.

With this said application integration problem decompose into the five sub-areas; database integration, information model integration, HMI integration, DE-tool integration and integration with other applications.

Database integration is the problem of interfacing
application in memory local data with a database (or in simplest case a file system). If an application comes with a database there is apriori no need to replace the database. However, integration of applications from different vendors using different databases will most likely result in replacement of the different databases with one common to ease system maintenance and lower licence fees. A common data access API will make such a database replacement easier.

Information model integration is the problem of integrating applications having overlapping information models; i.e. the same type of object is modelled in both applications. Normally independently created information models are different, e.g. object type names are different, relations between object types are different and properties are different. Either standardisation of information models or mapping of the different information models can solve the problem. Information model standardisation result in a common naming and meaning of object types, relations and properties. Mapping results in translators for data between the different models.

HMI integration is the problem of having the various application specific displays and dialogs to appear in a co-ordinated way with the same style. Particularly within a SCADA/EMS/DMS uniform desktop and dialogs is a requirement. Another HMI integration problem is to adapt presentation to fit with the information model actually used in a system. Object types relations and properties visible through the HMI shall fit exactly with what is used by installed applications, neither less nor more. Object type related HMI displays (e.g. form or tabular displays) shall present properties for installed applications in a seamless way, i.e. it is not acceptable to have separate displays (e.g. form or tabular) for different applications. At installation of a new or upgraded application added or changed relations or properties shall also appear in corresponding object type related displays.

The DE-tool integration problem is close to the HMI integration problem but with a stronger emphasis on flexibility in adaptation to new or changed information models (new or changed object types, relations and properties).

Integration with other applications concerns exchange of data where one application appears as producer and another as consumer. To get de-coupling between applications an API and information model for the data exchange is necessary. Another important de-coupling is to keep the knowledge of the producer-consumer association strictly by the consumer leading to a publish-subscribe kind of API. Also the producer and consumer execution needs to be de-coupled so that they can run asynchronously resulting in the requirement for a messaging system in the platform.

**External connections**

The open SCADA/EMS/DMS platform also support communication with external systems but with an emphasis on data exchange. The focus on data exchange also ties to work processes where data in different stages of refinement is transferred between systems. An open SCADA/EMS/DMS will make increasing use of the web for HMI. It will integrate with, office applications, vertically with devices having increasing intelligence, other SCADA/EMS/DMS and with other IT-systems. As WANs will be used in this integration the security becomes important.

**HMI, the web (5)**
The web will be used for access of the previously closed SCADA/EMS/DMS. A standard web browser will be used to access measurements, diagrams and calculation results. In the simplest case a web server in the SCADA/EMS/DMS will generate dedicated HTML pages. More advanced displays (e.g. schematic diagrams) will be drawn by Java applets or ActiveX controls provided by the web server.

A web based HMI will also facilitate a seamless integration between different applications as discussed more below.

**Office integration**

Office applications like Microsoft Word, Excel and PowerPoint are currently available at most office computers. Hence they are well known and most office employees are experienced users of them. An open SCADA/EMS/DMS shall be capable of providing measurement data and calculation results to be used by the office applications. The mechanism within the Windows operating system used to exchange data between application components is Microsoft COM. A SCADA/EMS/DMS that want to provide data to office applications in a Windows environment shall implement COM interfaces available in the office computer. In addition to the COM interfaces dialogs used to configure the SCADA/EMS/DMS connection is needed.

**Vertical integration (4)**

As the communication bandwidth increases more intelligence will move into remote devices, they become more intelligent (Intelligent Electronic Devices, IEDs). SCADA systems will also connect directly with SCSes (Substation Control Systems) and these connections will replace RTUs. This will relive the SCADA from some of its work but old devices and RTUs will yet stay for long and require support by the SCADA.

Configuration of RTUs, IEDs and SCSes will be made through tools. Two levels of integration with a SCADA/EMS/DMS can be imagined. If the device configuration tool is separate from the SCADA/EMS/DMS the device configuration parameters will be uploaded and used in the SCADA/EMS/DMS DE-tool. The other level of integration is a direct integration of the device configuration tool with the SCADA/EMS/DMS DE-tool. In this case the device will be downloaded from the integrated DE-tool.

On-line communication with the devices historically has been over highly specialised protocols (e.g. RP570, DNP and the TASE suite for inter centre communication). As
the communication bandwidth in the past has been low, much effort has gone into compacting data in the communication frames. This has resulted in complex and inflexible protocols where addition of new data types required changes in the protocol. With the rapidly increasing communication bandwidth (e.g. in WANs) there is no longer a need to put focus on compacting data. In fact, with protocols like IIOP or XML document formatting the need to manually create communication frame layouts as done for existing RTU and TASE protocols completely vanish.

**Model data exchange (3)**
Exchange of model data between different SCADA/EMS/DMS will increase due to changes in utility structures or the need to perform more accurate calculations on the power network. When a utility structure change due to the sale or acquisition of portions of the power system the model for that part for the power system will be moved from the seller to the acquire. This require support for extraction of the related model from the selling utility SCADA/EMS/DMS and merge of the extracted model into the acquiring utility SCADA/EMS/DMS. Increased accuracy in calculations can be achieved by using a larger model including more objects modelling the power system. Typically an interconnected power system is owned by several utilities. To make calculations on the complete power system require model data from all utilities resulting in exchange of data between the utilities. The above data exchange result in a number of problems. The different utilities will most likely use slightly different information models resulting in the need to make a translation between information models. Another problem appears in the boundary where the same equipment is modelled separately and possibly differently by the two utilities. Differences typically appear in naming schemes, aggregation of objects (e.g. measurements aggregated by power-lines/transformers or by bays or by breakers) and object models (e.g. a transformer modelled as a transformer or a load). A third problem is the data exchange format. By agreeing on a common information model for the data exchange information model differences can be isolated to become a vendor problem. Each vendor then has to adjust to the common information model. The mapping of the boundary model require tool support for cutting out non overlapping data and fitting boundary objects from different models together.
The format of the exchanged data has to be standardised. Traditionally column oriented or delimited formats have been used. Such formats are inflexible and hard to change which has resulted in the requirement to use self-defining formats. XML support self-defining formats and is attractive as it enables integration using the web and the extensive tools support available due to the rapid development of the web. RDF is an extension to XML allowing not only exchange of self defining data but exchange of information model information enabling a client to make intelligent decisions on data.

**Integration of IT-systems (2)**
Within utilities various and different work processes exist (e.g. network operation, customer support and billing, engineering related to the power system, asset management, work order management, enterprise resource management etc.). Different IT-systems have evolved to support the various work processes. These IT-systems has little or no interconnections resulting in error prone manual data exchange and use of different HMI systems having different dialog principles and styles. This result in needs for integration and a common harmonised HMI.
Integration of IT-systems follows much of the above discussion. Work process typically generates some data in one IT-system (e.g. engineering of a new substation). In subsequent steps (e.g. order substation components, build the substation and enter it into a SCADA/EMS/DMS) parts of this data is transferred into other IT-systems. The exchanged data needs to have standardised information model and exchange format. The most flexible media for the exchange is a text file (i.e. a document) in a self defining format (e.g. XML) that is automatically generated by the producing IT-systems and automatically processed by the consuming IT-system. The simplest transfer of the data is via a distributed file system or FTP. By using a messaging system (also called message oriented middleware, MoM) an automated and asynchronous connection of the producing and consuming IT-system can be achieved.
Harmonisation of HMI systems requires use of the same dialog principles and style guides so that communication with different IT-systems gives the same look and feel. Next step is to integrate the HMI for different IT-systems in the same desktop using common root dialogs making the IT-system to virtually appear as one system. This level of integration however requires a common authority system. Integration will also support the work processes such that they flow through the different IT-systems in an intuitive and non-disruptive way. The web is a good platform for this kind of HMI integration.

**Security**
Making a SCADA/EMS/DMS open and using WANs and mobile networks as communication backbone also result in high demand for security. The security will be of outmost importance for all interactions with the power system. There will be cipher code and authentication for mission critical data and digital signatures identifying who has been doing what for critical measures.

**Standards**
Integration of applications, IT-systems and HMI require standards. Standardisation bodies like W3C (World Wide Web Consortium [3]), OMG (Object Management Group, [1]) and IEC (International Electrotechnical Commission [4]) serve the IT-industry. In addition to these large companies like Microsoft provide de-facto standards and specialised consortiums provide industry niche standards.
like OPC foundation (OLE for Process Control [5]). For the utility industry IEC TC57 (Technical Committee 57) is in charge of IT-system standards. Currently the two TC57 working groups WG13 and WG14 are developing IT-system related standards. WG13 is mainly dealing with standards related to the internals of and exchange between SCADA/EMS/DMS [6]. WG13 standards have the IEC number 61970. WG14 is mainly dealing with standards related to exchange between IT-systems [7]. WG14 standards have the IEC number 61968. There is an overlap between WG13 and WG14 concerning information models due to the fact that both deal with power systems. For this reason the work in WG13 and WG14 is closely co-ordinated.

Within OMG the Utility DTC (Domain Technology Committee) do utility related standardisation work. The DAF (Data Access Facility [8]) is a standard from the Utility DTC. For electronic exchange of data two levels of standardisation is required. First an interface (or API) is required so that an execution thread within a computer process can call the operation of retrieving or delivering the data. Second an information model describing the data is required so that an application programmer can program the appropriate treatment of the data. The information model can be implemented directly in the API (it becomes hardwired in the API) or can describe the content data conveyed over the API.

**Interfaces**

As mentioned above, two major interfaces technologies exist, CORBA from OMG and COM/DCOM from Microsoft. Both are well suited for wrapping of legacy software. CORBA is mainly a Unix technology (though it works well also for Windows) and COM/DCOM is a Windows technology. For development of new non real-time software Java is an alternative as it support interfaces as well.

For the utility industry two APIs are currently evolving, the DAF and DAIS (Data Acquisition from Industrial Systems [9]).

The DAF is a generic API for retrieval of data that can be used with any kind of information model. The DAF is used in similar way as database APIs like ODBC. The DAF is however easier to use than ODBC. It is well suited as an API for initialisation of applications local in memory data. The DAIS is an API for efficient transfer of real-time measurement data and is based on the OPC specifications Data Access [10] and Alarms and Events [11]. OPC is a COM/DCOM API that has become the dominating standard for industrial control. Within the utility industry Unix is the dominating operating system and an API like OPC does not exist. When developing DAIS there are a number of reasons to make it similar to OPC as, benefit from the success of OPC, use of a proven technology and to make bridging or porting simple. DAIS is evolving and at the writing of this paper it has not yet become a standard.

Both the DAF and the DAIS will evolve into IEC standards and will be assigned numbers 61970-4xx (xx ∈ {01-99}). Also other API standards than these will develop, e.g. standards for authority, control, historical data access etc.

**Information models**

An information model describes the structure and meaning of data. Utility specific information models typically describe the power system or data used by SCADA/EMS/DMS applications. Information models also describe the data in message exchange between applications or IT-systems. Several languages exist that can be used to model information. UML (Unified Modelling Language) is such a language that has become widely used. UML has a graphical notation that is efficient to communicate information models between humans. This is an important aspect when standardising information models and UML has been chosen the language for information model standards within IEC TC57.

Based on work initiated by EPRI the CIM [12] (Common Information Model) information model standard has developed. The CIM mainly describe the object types that appear in a power system and configuration data that SCADA/EMS/DMS applications use. The CIM is developed by WG13 and the standards are numbered 61970-3xx (xx ∈ {01-99}). Information models as well as formats for the data being exchanged between IT-systems are being developed by WG14. WG14 has not yet adopted UML as the information modelling language but are using XML as the data exchange format.

**III. CONCLUSION**

**From product to concept**

The traditionally SCADA/EMS/DMS systems will evolve into concepts containing smaller independently released products. The different products will be adapted to emerging standards and may come from different vendors. There will be the traditional vendor that take full responsibility for the delivery and installation at the customer site and vendors that specialise on one or a few of the different products. There will also exist vendors that do not have own developed products but are specialised on installation or integration of products from other vendors.

**Moving target, rapidly evolving systems**

Market and utility structure will continue to change and together with technology changes there will be a requirement for continuous development of SCADA/EMS/DMS systems. This will lead to shortened delivery times and frequent upgrades to new releases of the different products.

**Standardisation important**

To get full flexibility for the utilities to choose vendors and solutions the evolution of standards are of outmost
importance. Standards define interfaces between products and common information models that are required to divide systems into exchangeable products.

IV. BIOGRAPHIES

Lars Gräsberg was born in Lindfors, Sweden, on September, 1968. He graduated with Master of Science in Electrical Engineering from Royal Institute of Technology, Stockholm. His employment experience is in the field of SCADA and Energy Management Functions at ABB in Sweden. He is the R&D Manager for the SCADA/EMS/DMS product S.P.I.D.E.R. since 1998.

Lars-Ola G Österlund is currently working as a senior analyst on software architecture and information modeling at ABB Automation Systems, Power Utilities Division in Västerås, Sweden. He received a Master of Science in Electrical Engineering at Lunds Institute of Technology, Sweden 1975 and a diploma on Artificial Intelligence and Expert systems at Linköping Institute of Technology in Linköping, Sweden 1989. Since 1975 he has been employed by ASEA and later ABB. Within ASEA/ABB he has been working with development of software in the fields of communication, EMS network applications, nuclear power plants applied Artificial Intelligence and Expert systems. He has been working with the software production and maintenance process including systems integration and testing. He has also managed R&D groups in these fields.

V. GLOSSARY

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>API</td>
<td>application program interface</td>
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<tr>
<td>CIM</td>
<td>common information model (for utilities)</td>
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<td>COM</td>
<td>component object model</td>
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<td>CORBA</td>
<td>common object request broker architecture</td>
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<td>DAF</td>
<td>data access facility</td>
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<td>DAIS</td>
<td>data aquisition from industrial systems</td>
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<td>DCOM</td>
<td>distributed COM</td>
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<td>DE-tool</td>
<td>data engineering tool</td>
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<td>DMS</td>
<td>distribution management system</td>
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<td>DTC</td>
<td>domain technical commettee within OMG</td>
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<td>EMS</td>
<td>energy management system</td>
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<td>EPRI</td>
<td>Electric Power Research Institute</td>
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<td>IDL</td>
<td>interface definition language</td>
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<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<td>IED</td>
<td>Intelligent Electronic Device</td>
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<td>IOP</td>
<td>Internet inter-ORB protocol</td>
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<td>MIDL</td>
<td>Microsoft interface definition language</td>
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<td>ODBC</td>
<td>open database connect</td>
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<td>OLE</td>
<td>object linking and embedding</td>
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<td>OMG</td>
<td>Object Management Group</td>
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<td>OPC</td>
<td>OLE for process control</td>
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<td>object request broker</td>
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<td>relational database management systems</td>
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<td>resource definition framework</td>
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<td>remote method invocation</td>
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<td>remote terminal unit</td>
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<td>SCADA</td>
<td>supervisory control and data acquisition</td>
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<td>substation control system</td>
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<td>TC57</td>
<td>technical commettee 57 (power system control...)</td>
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<td>UML</td>
<td>unified modelling language</td>
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<td>World Wide Web Consortium</td>
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<td>WAN</td>
<td>wide area network</td>
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<tr>
<td>WG14</td>
<td>working group 14 (system interfaces for DMS)</td>
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<tr>
<td>XML</td>
<td>extensible markup language</td>
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</tbody>
</table>

VI. REFERENCES

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