Cost-benefit analysis of migrating the ADMS to the computing cloud

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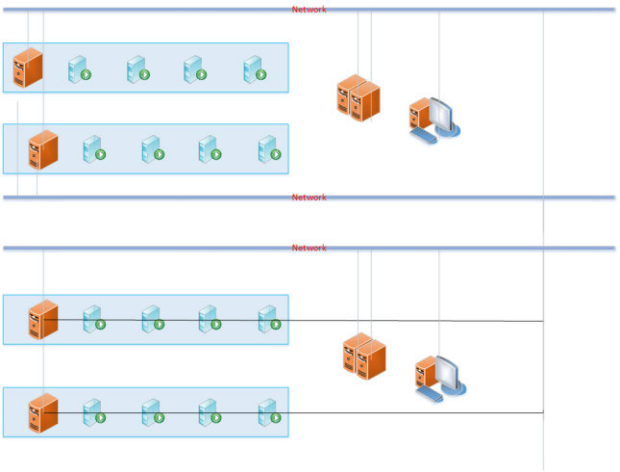
***Abstract*—Although the concept of cloud computing is known for more than a decade, not all industries are equally ready to leverage its benefits, e.g. minimum upfront investment costs, significantly lowered hardware administrative burden, vast scalability. Most Industrial Control Systems (ICS) specifically designed and developed for the Smart Grid industry still follow the traditional architecture and are not leveraging the benefits brought by the cloud. One such ICS is the Advanced Distribution Management System (ADMS), which relies on vast network models to monitor, control and optimize the work of electric power distribution systems. The goal of this paper is to analyze the costs of shifting the ADMS from on premise to a cloud solution. In the discussion, we compare two cloud providers, Microsoft's Azure and Amazon Web Services. We estimate the cloud computing costs for small, medium and large utilities and compare them to the traditional solution.**

I. INTRODUCTION

Modern information systems often incorporate software solutions with extremely high processing, memory and input/output operation requirements. The hardware used to support these systems needs to be maintained daily, and in every 5-7 years it needs to be replaced, which requires resources, money and time. The Industrial Control Systems (ICS) used in Smart Grids, the modern electric power systems, are one example of such software systems. The primary goal of this research is to perform a cost-benefit analysis of migrating the ADMS from an on premise (i.e. servers and administrators located in the DSO's control/data center) to the computing cloud.

A. *Advanced Distribution Management System*

Utilities need advanced power applications for meeting the needs of greater reliability and fewer emissions. The Advanced Distribution Management System (ADMS) is used to monitor, control and optimize electric power distribution systems, with millions of customers and millions of data points. The ADMS calculation engines work with network models containing tens or hundreds of thousands of transformers, power lines and other equipment. ADMS Scheme example is provided in the picture 1, where multiple machines are connected in one area and areas are connected through local network to form a zone.



Picture 1 - ADMS Scheme example

B. *Cloud Computing*

Clouds have emerged as a computing infrastructure that enables rapid delivery of computing resources as a utility in a dynamically scalable, virtualized manner. The advantages of cloud computing over traditional computing include: agility, lower entry cost, device independency, location independency, and scalability [1]. Definition of Cloud Computing of National Institute of Standards and Technology is [2]: Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. Further, NIST has described three service models [2]:

- **IaaS (Infrastructure as a Service)**: The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer can deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).
- **PaaS (Platform as a Service)**: The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired

applications created using programming languages, libraries, services, and tools supported by the provider.3 The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

- **SaaS (Software as a Service)**: The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, except for limited user specific application configuration settings.

Cloud can be classified as private, community, public and hybrid [2]. Private cloud is controlled and access by people within certain organization. In case of community cloud, specific community of consumers from organizations can use cloud infrastructure. Public cloud can be accessed by public. In case of hybrid infrastructure, cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds) [2].

II. RELATED WORKS

In [3], certain issues that accompany cloud computing have been discussed. Security issues have been identified as the biggest, followed by performance and availability. Another challenge discussed in [3] was higher cost of communication, which presents in cloud solution, but not in on-premise solution. Security concerns were discussed in [4], where fault tolerance, service availability, data migration, data confidentiality and integrity were pointed as major issues. Further, authors in [4] have proposed five different deployment models as a resolution to security concerns, identified by users. Migration from on-premise to cloud solution was analyzed in [5], where authors concentrated on PaaS migration, giving a migration process framework, while outlining major steps and concerns. Migrating enterprise applications to cloud was analyzed in terms of planning which servers to migrate and ensuring correctness of security policies on migration in [6]. Solution involved hybrid cloud deployment, showing potential benefits, as well as feasibility of automatic and assurable reconfiguration of reachability policies, as enterprise applications are migrated to hybrid cloud models [6]. Case study, which included migration of IT system in oil & gas industry from an in-house data center to Amazon EC2 (Elastic Compute Cloud), showed that the system infrastructure would have cost 37% less over 5 years on Amazon EC2, and using cloud computing could have potentially eliminated 21% of the support calls for this system [7].

III. METHODS

The processing power, memory and input/output operations needed by these systems are extremely high. Distribution System Operators (DSO) incur various costs when they operate the ADMS in their own data center, e.g. administrators are needed for maintaining hardware and network, space needs to be provided for hardware and administrators, hardware needs to be replaced in 5-7 years. Moving the ADMS to a cloud computing platform shifts the burden of hardware maintenance from the DSO to a cloud provider. By shifting to a cloud solution, the DSO does not have to invest in hardware maintenance and might focus on its core business, which is providing electricity to its customers.

The hardware costs necessary to support small, medium and large ADMS systems were calculated. The amount of processing power (CPU), memory and input/output operations (IOPS) used in calculations were obtained through measurements obtained from real-life ADMS solutions. We also compare different cloud computing vendors for the cloud-based solution. Microsoft's Azure and Amazon Web Services (AWS) were chosen from a vast spectrum of active cloud providers and compared based on expected costs. Cost of cloud-based solutions are calculated by using vendors pricing at the time of this paper.

A. *ADMS in Cloud*

Utilities using ADMS solutions have from tens of thousands of customers, to over millions of customers. In Table 1 we estimate the number of customers, CPU and memory requirements for small, medium and large utilities.

TABLE I.
UTILITIES AND CUSTOMER COVERAGE

	Number of customers	Number of vCPU	Number of vRAM
Small	0-300,000	450-500	1600-1700
Medium	300,000-1,000,000	780-830	2900-3100
Large	>1,000,000	1150-1250	6600-6800

To show benefits for moving from on premise to cloud computing platform, the costs of traditional and cloud-based solutions are compared. Additionally, we compare the prices on the Microsoft Azure and Amazon Web Services (AWS) platforms. The estimated CPU and memory requirements were used to determine the minimum hardware requirements for small, medium and large ADMS. Finally, we calculated the cost of ownership of that hardware for a period of 5-7 years. Also, for the on-premise solution, cost for personnel, space and electricity must be included in final price for the same period. For comparative purposes of maintenance cost, in cloud based solution, machine prices available on Azure platform and Amazon Web Service were used. One of the important advantages cloud based solution provides is the capability of turning off underutilized (i.e. unused) virtual machines. This reflects to the final price, since the business policy of cloud providers is that we pay what we

use ("pay as you go"). Downside of the cloud based solution is the uncertainty of cost, as cloud providers can modify pricing model at any time. Also, upside might be the possibility of discounts for Smart Grid companies.

IV. RESULTS

Using estimated CPU and memory, we have come to conclusion which machines can be used, to run ADMS for different sized utilities. Industry experts estimate that calculated upfront investment costs for supporting data centers goes from 1 million dollars for small, 1.4 million dollars for medium and up to 2 million dollars for big utilities. The assumptions are (for the software quality sake) that the hardware should be replaced every 5-7 years, which entails repetition of these costs. If we use 5 years as a period for hardware replacement, we can scale this costs for monthly basis and get estimated numbers: 17.000 dollars, 24.000 dollars and 34.000 dollars for a small, medium and large utility, respectively. This estimated costs include licenses, which are 15% of the whole cost. As this is on premise solution, hardware is bought at the very beginning of deployment process, which means that hardware maintenance, electricity, facility renting and fees for various employees remain as monthly expenses. In Table 2, monthly cost comparison for on premise and cloud solutions is provided.

TABLE II.
MONTHLY COST COMPARISON

	On-premise [$]	Azure [$]	Amazon [$]
Small	17,000	36,500	34,500
Medium	24,000	70,000	66,500
Large	34,000	61,500	69,000

In case of cloud solution, estimated expenses are different, i.e. there is no upfront investment and maintenance costs are distributed differently. Using the same estimated values for CPU, memory and IOPS for the machines which were used in on premise solution, we have calculated monthly expenses of the system. In case of a small utility, monthly cost is around USD 41,000, if the system is deployed on a cloud platform, specifically on the Microsoft Azure cloud platform. The same calculation was done for a medium and a large utility, which gives the expected costs of USD 79,000 and 86,000, respectively. For comparison, the same calculation was performed on another cloud platform, Amazon Web Services. For a small, medium and large utility, calculated expenses are USD 38,000, 75,500 and 97,000, respectively. If one of the main advantages of cloud platform is used, the ability to shut down unused machines, some cost reduction is noticed, i.e. some machines can be shut down during the night. New costs for a small, medium and large utilities are USD 36,500, 70,000 and 61,500, respectively. These prices are for Azure platform. In case of cost reduction for Amazon Web Services, it has come to next calculations: USD 34,500, 66,500 and 69,000 for a small, medium and large utility.

V. DISCUSSION

Even though the prices for on premise solution seems smaller, there are hidden costs which are not included in the initial price. One of the advantages of cloud based solution is elimination of system administrator, since the maintenance is shifted to the cloud provider, which provides 24/7 support to the utility. Another advantage of cloud solution is loss of licenses, because cloud virtual machines have licenses included, which represents the cost of 15% of on premise solution. In this paper, we are not calculating the cost of databases needed for running the ADMS software, as this can be used for further research. Also, security and optimization of different cloud solutions are going to be considered in further research.

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