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Enhancing The Network Capacity Using Fgsn In Aura-Nms For Leo Satellite Constellation

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ABSRACT

In recent decades, the advances in Distributed Generation (DG) technology and environmental considerations have been gradually reshaping the current power networks because the need for downloading increasing amounts of data from orbiting satellite resources is an ever present challenge for space designers. Our research is motivated by LEO satellite constellations and other space missions to maximize the total data down linked from orbiting satellite systems through power distributed networks. However, the AURA-NMS is exploited as a cost-effective tool for our new communication infrastructure with reliable, flexible, autonomous as well as collaborative network control; their work is inverted from the effort as it is assessing space-to-ground coverage, while we are interested in ground-to-space coverage, how much data the ground station network can support downloading from a collection of satellites. In this paper, we propose an analytic models and tools to describe the communication between the ground stations and orbiting satellite in an autonomous and collaborative power efficient along with higher fidelity constraints on network capacity.

1. INTRODUCTION

Various technologies for distribution of power among network stations and the network capacity for downloading data from satellite systems have been analyzed and identified to develop the performance of satellite communication. Since the need for downloading increasing amounts of data from orbiting satellite resources is an ever present challenge. Also requires the power to be distributed among the network stations. Here the use of smart grid technology place main role for distribution of power resources.

The subsystems in satellite networks requires large amount of power, but this power is needed while it downloads data and not all the time. So it requires power in a distributed manner which saves energy. To solve this above problem, Distributed Generation Technology was first developed with DNO’s. To solve this above problem, Distributed Generation Technology was first developed with DNO’s [1] [7].

Distributed Generation (DG) is a promising solution to many power system problems such as voltage regulation, power loss, etc [10]. The location in the power system for DG placement is found to be very important. As demand increases, the utility generates more electricity. Once demand increases beyond a certain level, however, the capacity of the generation, transmission, and distribution systems can become constrained. So the next technology came into existence is Autonomous Regional Active Network Management System (AURA-NMS), it gives power in an autonomous and collaborative way. But the drawback again we faced here was the network capacity upon downloading large amount of data using X-Band (say 8GHz to 10GHz). The AURA-NMS focuses on distribution of power to Remote Telemetry Unit

(RTU), which is used for minimum downloading purpose. Distribution of power to RTU is not a challenge rather distribution of power to Ground Station Networks is a ever facing challenge among the communication networks.

The Proposed work focuses on power distribution for Ground Station Networks (GSN) by replacing RTU with GSN and also enhances the network capacity [10] by increasing the antenna aperture of ground station antenna. Here we use Low Earth Orbit (LEO) satellites, since it's about 600km to 800km from earth, downloading of data can be done every effectively without much loss in signal strength. Following will explain about the problem description (2), Concept of AURA-NMS (3), Ground Station Networks and Antennas (4), (5) and conclusion & future works (6).

2. PROBLEM DESCRIPTION

An alternative approach under consideration by utilities is to satisfy demand locally and incrementally by investing in distributed generation. DG facilities are strategically sited to deliver electricity where it is needed. This can relieve capacity constraints on the generation, transmission, and distribution systems and obviate the need to build new facilities [5]. Generally, DG can be best fitting into different applications, including; emergency or back-up supply, peak loads, consumer's complete requirements, shortage of generation, and combined with most of the other possible applications. Therefore, the proper allocation of distributed generation may lead to the following system support benefits: Loss reduction improved utility system reliability, Voltage support and improved power quality, Transmission and distribution capacity.

2.1 THE OBJECTIVE FUNCTION

The objective function for distribution system expansion will be considered as the sum of four terms [11]:

- Cost of substation expansion (fixed & variable);
- Cost of the distributed generation DG's (fixed & variable);
- Cost of the new feeders upgrades (fixed); and
- Cost of the energy losses (variable).

The variable cost is the cost of operation and maintenance of equipments and it mainly depends on equipments loading. The mathematical formulation (2.1) of the objective function is described in equations below,

Minimize capital investment and operational cost:

$$J = C_U + C_{DG} + C_F + C_L \qquad \ldots (2.1)$$

Where,

C_U = capital and operation cost for substation expansion,

C_{DG} = capital and operation cost for DG,

C_F = capital cost for upgrading the feeders,

C_L = cost of energy losses

2.2 CONSTRAINTS

The following constraints are considered:

i. **Total Power Conversation:** The summation of all incoming and outgoing power over the feeders, taking into consideration the feeder's losses and the power supplied by DG.
ii. **Distribution Feeder's Thermal Capacity:** Power flow in feeders must be within their capacities.
iii. **Distribution substation's Capacity:** The Summation of total power delivered by the substation's transformers to the network must be within the substation's capacity limit.
iv. **DG Operation Limits:** The DG's generated power must be within the DG's capacity.
v. **Voltage Drop Limits:** The voltage level at different buses must be within predetermined value.

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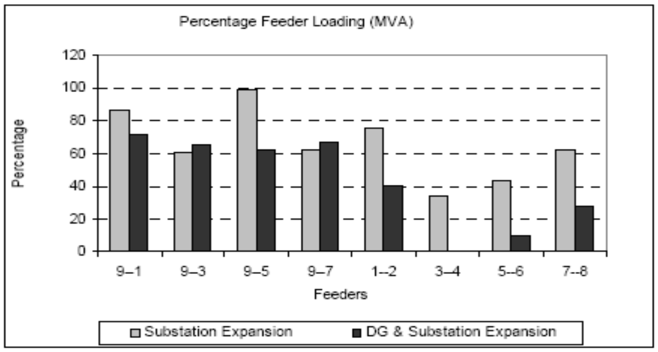

Figure 2.1 Percentage Feeder Loadings

This model is to find the optimal planning cost of the expansion to meet the load growth. This cost includes the capital cost and the operational cost of the substation and the DG's. The cost also includes the cost of the power losses in the system and the cost of the feeders upgraded when their power flow exceeds their thermal capacity limit.

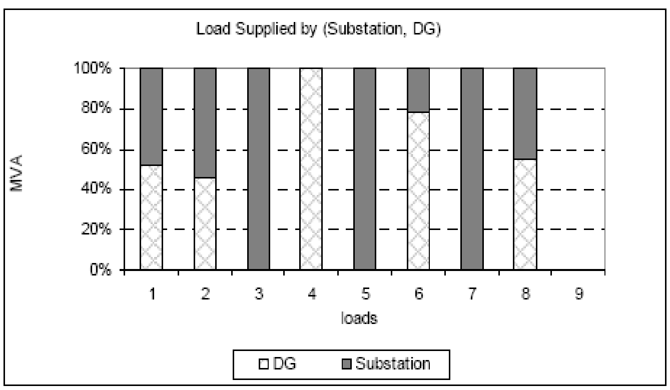

Figure 2.2 Load Supplied by Substation and DG for the DG option

The results show that the DG's introduce economical and electrical benefits to the system. The planning cost of the DG option is better than the planning cost of the substation expansion by 8.7%. The voltage profile of the DG option is better than the voltage profile of the substation expansion. DG improves the percentage power loading of the feeders and keeps the power flow through the feeders reduced. Further enhancement deals with new technology namely, SCADA, using smart grid technology.

3. RELATED WORK

Smart Grid will allow a two- way flow of electricity and information that is capable of monitoring everything from power plants to customer preferences and individual appliances/equipment. SCADA is an acronym for Supervisory Control and Data Acquisition [7]. SCADA systems are used to monitor and control a plant or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining and transportation. These systems encompass the transfer of data between a SCADA central host computer and a number of Remote Terminal Units (RTUs) and/or Programmable Logic Controllers (PLCs), and the central host and the operator terminals.

A SCADA system gathers information (such as where a leak on a pipeline has occurred), transfers the information back to a central site, then alerts the home station that a leak has occurred, carrying out necessary analysis and control, such as determining if the leak is critical, and displaying the information in a logical and organized fashion. SCADA systems consist of:

- One or more field data interface devices, usually RTUs, or PLCs, which interface to field sensing devices and local control switchboxes and valve actuators.
- A communications system used to transfer data between field data interface devices and control units and the computers in the SCADA central host. The system can be radio, telephone, cable, satellite, etc., or any combination of these.
- A central host computer server or servers (sometimes called a SCADA Center, master station, or Master Terminal Unit (MTU).
- A collection of standard and/or custom software [sometimes called Human Machine Interface (HMI) software or Man Machine Interface (MMI) software] systems used to provide the SCADA central host and operator terminal application, support the communications system, and monitor and control remotely located field data interface devices.

But this technology does not suitable for satellite communication that needs power in a collaborative way. This leads to the growth of autonomous system which gives power in distributive and collaborative manner for ground networks, namely AURA-NMS, here the terminal unit is RTU, requires low power for data transmission, so distributing power to the lower power terminals is not a challenging task. Distribution of power to ground station networks is a challenging task. In this paper, our motivation is to distribute power for terminals which requires large power for downloading data from satellite in a timely manner, that is, according to the pass. Since we replace the existing terminals with large power networks, some shortcomings will exist such as low network capacity, etc. To improve the network capacity, ground station antenna is modified.

4. AURA-NMS APPROACH

AuRA-NMS is part of the drive to develop ‘intelligent’ or ‘smart’ networks. Like the Smart Grid and IntelliGrid vision, it is predicated on the deployment of distributed computing resources with the use of cost effective communication links between those resources [3].

One of the goals of AuRA-NMS was near term demonstration on in service medium voltage networks. In current centralized SCADA system, all outstation RTUs in the power system sites send its most current status and information through the communication network to the control centre. In the control centre, these transmitted data will be scanned and analyzed by the system control software program to pick out any mismatch occurred at the corresponding outstation.

The main control node will issue control messages to the RTUs connected in the network. Each outstation RTU is modeled as communication nodes which collects measurement report from sensors and deliver commands to control relays. All these nodes are connected together via heterogeneous communication links (e.g. leased digital fibers, private pilot cables, PSTN phone lines, radio, mobile cellular networks) with relatively low bandwidth (a few kb/s to 2Mb/s).

At higher voltage sites (e.g.132/33KV), data concentrators are often adopted to collect information from downstream RTUs and the communication channels are more secure and robust with better reliability (e.g. triangulation, duplicated routes). In an autonomous management system, controllers (CONTR) could be integrated in e.g. existing power network sites. All the data collected from the power network sites (both analogue and digital measurements) could be transmitted to the controllers which have enhanced data processing and control functionalities. Only a small portion of data would be retransmitted to the control centre (M) for further processing.

AuRA-NMS controllers are ubiquitously deployed across the power network and responsible for automatic system configuration, fault restoration and voltage control [6][8]. Propose the appropriate communication architecture to meet the requirements of AuRA-NMS distributed control system. Determine the impact of underlying communication networks characteristics on distributed power network control systems. Assess the impact of e.g. non-uniform and multi-type sensor/actuators distribution, traffic patterns on the communication infrastructure.

Asses the performance of the communication network when power network is undergoing anomalous operation conditions. Assess impact on power network normal operations (and controllability) under degraded/faulty conditions of communication network elements. Identify the cost-effective available communication technologies to facilitate AuRA-NMS and make the solution to be future-proof.

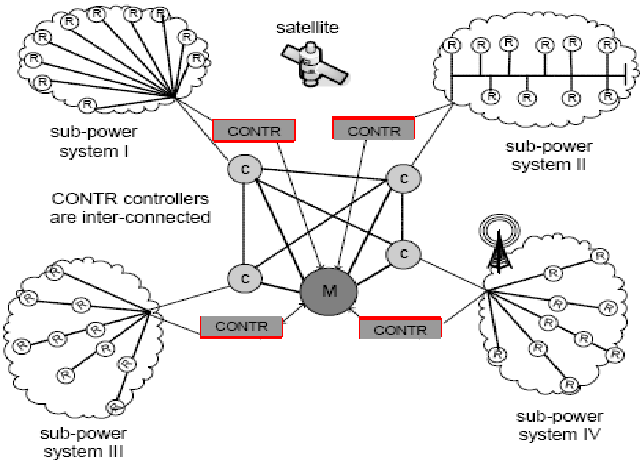

Figure 4.1 Architecture of AURA-NMS

This approach is now used for small terminals but its capacity can be done to large power terminals, so instead of using RTU's, Ground Station networks can be used in a federated way (FGSN). The fundamental purpose of a ground station (GS) is to enable communication between ground users and space assets [4]. In addition to the RF equipment needed for communication, ground stations traditionally have a suite of support systems for mission-specific data handling needs such as demultiplexing of data streams, encryption functions, data compression, time tagging, data storage, data quality measurements, and spacecraft ranging. Normally, GSN requires more power because it performance not only receiving and transmitting data, but also it schedules the process using algorithms, it stores the data, that too, separately as image database and constraint database, evaluation of function, propagating rules and giving direct interface to user.

In RTU's, there is no direct inter face to users, it does not contain database, scheduler, etc. It accesses those things from master terminals. But FGSN have every above component as an inbuilt one. It does not require a separate master terminal.

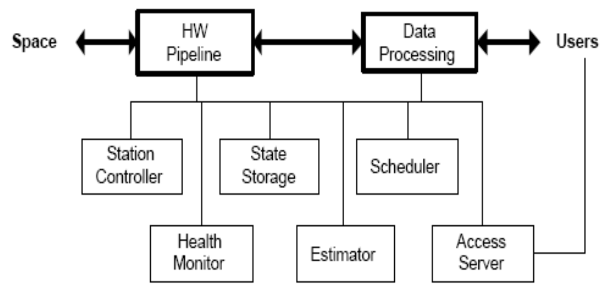

Figure 4.2 Components in FGSN

Here, the work can be enhanced with any of the above components to increase the network capacity. We are going to increase capacity of network using Ground Station Antenna, which is a component of GSN.

5. GROUND STATION ANTENNA

Antennas are a very important component of communication systems. By definition, an antenna is a device used to transform an RF signal, traveling on a conductor, into an electromagnetic wave in free space [9]. Antennas demonstrate a property known as *reciprocity*, which means that an antenna will maintain the same characteristics regardless if it is transmitting or receiving.

Here, in this work, a type of antenna called Cassegrain Antenna is used as ground station antenna. It is a parabolic shaped antenna where the gain and directivity is large when compared to other type of antennas. Antennas based on parabolic reflectors are the most common type of directive antennas when a high gain is required. The main advantage is that they can be made to have gain and directivity as large as required.

The basic property of a perfect parabolic reflector is that it converts a spherical wave irradiating from a point source placed at the focus into a plane wave. Conversely, all the energy received by the dish from a distant source is reflected to a single point at the focus of the dish. The position of the focus, or focal length (5.1), is given by:

$$f = \frac{D^2}{16 \times c} \quad \dots (5.1)$$

where D is the dish diameter and c is the depth of the parabola at its center. The size of the dish is the most important factor since it determines the maximum gain that can be achieved at the given frequency and the resulting beamwidth.

The gain (5.2) and beamwidth (5.3) obtained are given by:

$$G = \frac{(\pi \times D)^2}{\lambda^2} \times n \quad \dots (5.2)$$

$$BW = \frac{70\ D}{\lambda} \quad \dots (5.3)$$

where D is the dish diameter and n is the efficiency. The efficiency is determined mainly by the effectiveness of illumination of the dish by the feed, but also by other factors. Each time the diameter of a dish is doubled, the gain is four times, or 6 dB, greater.

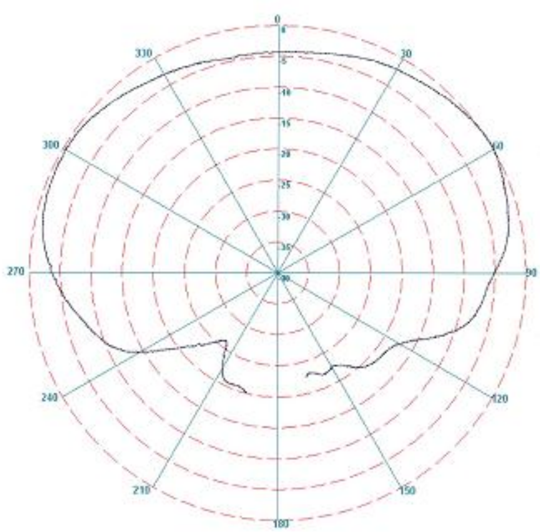

Figure 5.1 Beamwidth of increased aperture of Cassegrain Antenna while tracking from $-90° \ to + 90°$

If the beamwidth is high, then the network capacity is considerable upon downloading data [10]. Thus the capacity can be increased by increasing the size of aperture of the antenna.

6. CONCLUSION

Thus the AURA-NMS approach can be used for large power consuming terminals which is every useful upon downloading huge amount of data (say 8GHz – 10GHz) by placing Federated Ground Station Networks as terminals and by increasing the antenna's aperture of GSN we provide high beamwidth network capacity.

Further work can be carried with enhancing scheduling algorithm, propagating rules or providing more advanced secured database etc.

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