Open Interface System Protocols for Space Based Power Systems

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***Abstract*—Renewable energy systems have been recognized to play an important role in future environmentally friendly energy systems. An important source of renewable energy is solar power derived when solar panels intercept with incident solar radiation. The degradation effect of cloud obstruction has led to the consideration of space-based solar power systems. In space-based solar power systems, satellites with large solar panel payload transmit solar energy to earth-based rectennas. The deployment of multiple space based solar power satellites is necessary to ensure that more energy is derived from space based solar power. However, the realization of such a system requires the design of communication protocols between in-orbiting space-based power satellites. The use of such a system enables multiple receiving antenna ground stations to concurrently receive power from solar power satellites. The presented research aims to present the design of system protocols that enable the realization of this goal, considering heterogeneous solar power satellites and operational conditions. This is carried out while considering communications between in-orbiting space-based solar power satellites, along with satellite rectennas. Furthermore, performance analysis and investigations show that the use of the proposed solution enhances power accessibility and reduces deficit by an average of 18%.**

Keywords—Constellations, Mobile Rectennas, Space Solar Power Networks, Power Access

I. INTRODUCTION

The need to achieve energy security is important to be achieved in modern civilization. Moreover, there is an important focus on realizing intelligent data-driven energy systems. This has led to the need to integrate communication networks with future intelligent energy systems [1], [2], [3]. In addition, it is important to identify, and harness new energy sources in previously unconsidered locations i.e., [4], [5]. The need to achieve environmentally friendly operation of new energy sources has also been considered. This has led to the use of renewable energy sources such as solar, wind (onshore, and offshore), and space-based solar power.

Space-based solar power has received significant research attention [6], [7]. This approach of renewable power has the benefits of experiencing a low cloud occlusion with regard to solar radiation interception. In addition, space-based solar power provides a new form of renewable energy resource. The use and large-scale adoption of space-based solar power enables the transitioning away from the mix of fossil fuel-based energy sources used in electricity generation. Therefore, the use of space based solar power provides the benefit of climate change mitigation. In addition, space based solar power systems have a reduced reliance on earth's land resources in comparison to terrestrial based systems. Terrestrial based systems have a high land footprint especially when the deployment of large-scale solar farms is put into consideration. Furthermore, space-based solar panel systems are less prone and susceptible to theft in comparison to terrestrial based solar panel systems. Space-based solar power makes use of satellites launched into outer space. The launched satellites transmit the resulting power to the ground receiving antenna i.e., the receiving antenna (rectenna).

The design of space-based solar power systems requires that execution of different functions by the space and ground segment. Currently, the core function is that of transmitting electrical energy from the space segment to the ground segment. However, space-based solar power systems are also expected to provide power in a ubiquitous manner. This capability benefits from the mobility in orbiting satellites that have been launched into the low earth orbit. It is important that a constellation of in-orbit satellites is able to meet the power needs across multiple ground locations.

In this case, it is important to design new protocols enabling the ubiquitous provision of power from space-based solar systems. This is important in a case concerning the large-scale deployment of space-based solar power satellites, and corresponding ground stations. In this case, it is considered that an open ground station system and architecture is being used. The use of an open ground station has been recognized to improve the performance of satellite networks [8]. Furthermore, the consideration of space-based solar power systems has largely focused on single solar power satellites as seen in [9], [10], [11]. However, there is an increasing transition to the use of large-sized space structures and systems as seen in [12]. This makes the realization of space-based power satellites realizable. The use of such large-sized space structures in space-based power applications is beneficial due to the potential of high-power yield.

The realization of ubiquitous capability in space-based solar power systems is beneficial because it enables the supply of power to several terrestrial grid-limited regions. In addition, a ubiquitous capability also enhances the capacity of space-based solar power systems to address energy insecurity in regions that have experienced the occurrence of natural disasters. In such regions, the power infrastructure is no longer available for the provisioning of electrical power.

However, the realization of space-based solar power systems in this manner requires the realization of a space-based solar power network. The envisaged space-based solar power network that provides ubiquitous power to grid-limited regions requires the specification of new network functionalities, and roles. An important role in this regard is that of power forwarding. Power forwarding in this case requires the introduction of intersatellite transcetennas. In this case, a transcetenna is an onboard module capable of executing power signal transceiver between large-sized space-based power satellites. The proposed research presents system protocols to deliver the functionalities for the large-sized space-based power satellites incorporating transcetennas. In addition, this is done considering the case of an open system interface. An open system interface is deemed necessary considering the case where multiple vendors and original equipment manufacturers produce the large-sized space-based power satellites.

The focus of the proposed research is the presentation and discussion of the architecture for the proposed large-sized space-based power satellite network. The contributions of the research are further enumerated as:

(i.) First, the research proposes the computing and networking architecture for the proposed large-sized space-based power satellites inclusive of transcetennas. The computing architecture identifies and describes the role of data used by the large-sized space-based power satellite in realizing ubiquitous power provision to grid-limited regions. In this case, the grid-limited regions being considered are deemed to be under the coverage of the orbiting large-sized space-based power satellite. Furthermore, the satellites are deemed to be hosted in low earth orbit. The networking architecture describes the relations between the large-sized space-based power satellite's transcetenna, and the rectenna in the ground segment. The considered relations describe relations enabling the execution of power transmit to the ground station rectenna and forwarding through the transcetenna.

(ii.) Second, the research describes the functionalities to be executed by the networking protocols for the proposed large-sized space-based power satellite, and the ground segment. The description is done in the context of forwarding towards the realization of a ubiquitous power supply. In our consideration, there are multiple large-sized space-based power satellites across multiple planes in the low earth orbit. The networking protocols consider the need to achieve power routing and execute information transport. Information transport refers to the necessary modifications to the transmission control protocol (TCP) in the case of the large-sized space-based power satellite computing network.

The rest of the presented research is organized as follows. Section II presents the existing background work. Section III focuses on the computing and networking architecture for the proposed large-sized space-based power satellite. Section IV discusses the proposed open system interface for the space-based solar power network. Section V formulates the performance model and presents the simulation results. Section VI is the conclusion.

II. REVIEW OF BACKGROUND WORK

Petroni *et al.*, [13] identify the important technological advances that have enabled the resurgence of interest in space solar power applications. It also recognizes the different factors that have motivated different regional agencies to develop interest in solar power derived from the environment of space. The discussion in [13] recognizes the interests of different regions i.e., US, Europe, Japan, China, and Russia in harnessing solar power derived from space. The discussion has recognized the need to design solar panels to fit into new systems. This is necessary to adapt to the space environment. In addition, the different regional motivation for using space originating solar power is discussed. The general outlook of the discussion in [13] is that the increasing demand for access to power necessitates harnessing power from previously unconsidered locations such as space. However, the discussion of approaches enabling the integration of space originating solar power in a manner that benefits from data driven reconfiguration requires further research attention.

The research in [14] identifies and discusses the role of important components in the space solar power incremental demonstrations and research project (SSPIDR). The discussion in [14] extends [13] by describing the role of the power receiving entity at the ground station. The focus of the paper is on the identification and addressing of the role of the critical technologies enabling the realization of a holistic space power system focusing on projecting beams from space to earth. However, additional focus on the use of space orbital resources and the realization of corresponding ground coverage is required.

Plait in [15] discuss the tradeoffs associated with the use of different orbits for hosting solar power intercepting and beaming satellites. In addition, it presents a comparison of solar power from space with terrestrial solar power. In addition, the need to address the environmental challenges arising from the use of space solar power is recognized. The environmental challenge arising in this case emanates from the occurrence of light pollution. The occurring light pollution is recognized to negatively affect animal and plant life. In addition, the light pollution emanating in this manner significantly impairs the occurrence of ground based. In addition, it is identified that the inclusion of the launch costs makes space based solar power systems cost prohibitive in comparison to terrestrial based solar power system. Therefore, further research to make terrestrial based solar power system economically accessible is required. The discussion in [16] shares a similar outlook and presents results emphasizing the need to improve the efficiency of commercial space-fit solar panels to a high level comparable to that obtained in the laboratory environment i.e., research environment production space-fit solar panels.

The discussion in [17] recognizes the crucial role that a constellation of large-sized space solar power harvesting systems plays in increasing the power output from solar power systems. However, a holistic and cohesive end to end system management approach is required via the conduct of further research.

III. PROPOSED SYSTEM ARCHITECTURE

A. Computing Architecture

The discussion in this section presents the architecture of the proposed large-sized space-based power satellite. It is divided into three aspects. The first aspect focuses on the computing architecture. The second aspect focuses on the networking architecture. The third aspect discusses the role of supporting network protocols.

The computing architecture is expected to execute tasks related to data storage, processing and use in the reconfiguration of the proposed large-sized space-based power satellite. The computing architecture hosts entities that store and enable the use of data for determination of the functionality to be executed by the large-sized space-based power. The considered functionalities in this case are: (i) Power and Data forwarding for remote access via the transcetenna, (ii) Power transmission to the rectenna at a given location, and (iii) data indicating the inclusion of a new rectenna at a given ground location. The data required for the execution of forwarding is stored in the forwarding module entity (FME). The data required for determining the transmission to the rectenna is stored in the power supply module entity (PSME). The new rectenna availability indicator related information is stored in the new ground entity module (NGEM).

The FME receives data signifying the need to transmit power to another space-based power satellite. The considered transmission is done from the source large-sized space-based power satellites to other large-sized space-based power satellites. The role of the FME also enables the transmission of power to the aligning rectennas of small-satellite space-based power satellites. In this case, the small-satellite space-based power satellites realign their antenna to receive power from the source large-sized space-based power satellite. The data elements in the FME are the amount of requested power by the requesting small-satellite space-based power satellite or large-sized space-based power satellite, and the space segment identifier.

The PSME hosts data related to the power demand from the ground based rectenna at an epoch and given location. The power demand related data for rectennas at different locations and epochs is stored in the PSME. The PSME also evaluates the capability of a given large-sized space-based power satellite to meet the rectenna energy demand. In the case where the onboard power capacity is insufficient to meet the rectenna (i.e., location specific) power demand, the large-sized space-based power satellite transits into the forwarding mode. In the forwarding mode, the difference in the power demand i.e., power deficit is stored in the FME.

The large-sized space-based power satellite is expected to host a larger solar panel and battery payload in comparison to small satellites. Therefore, it is feasible to expect that large-sized space-based power satellites are able to transmit power to more ground-based rectennas. Therefore, it is important that the proposed large-sized space-based power satellites be aware of rectenna location. An awareness of rectenna location ensures that the limited communication window between the ground based rectenna and the space segment is maximized. In this regard, the location indicator and availability of ground rectennas aiming to receive power is stored in the NGEM. The NGEM is populated after a ground based rectenna sends own location. The location information is sent by the ground based rectenna after the successful transmission and reception of power from the large -sized space-based power satellite.

The relations between the FME, PSME, and NGEM are shown in Figure 1. As seen in Figure 1, there are four stages in the presented relations. Stage 1 involves data transmission from the nearest rectenna location server to the NGEM. The rectenna location is hosted in the rectenna location server associated ground station and is transmitted to the large-sized space-based power satellite. The NGEM sends the rectenna location to the PSME to enable the execution of decision making. The PSME makes decision enabling the power satellite to determine the need to execute microwave power transmission. The PSME transmits information to the ground based rectenna given the availability of a rectenna in the ground coverage area. In addition, the PSME sends the required power (in the case of a deficit) to the FME. The computing entity in the FME enables t the exchange of the required amount of power between in-orbiting space-based power satellites.

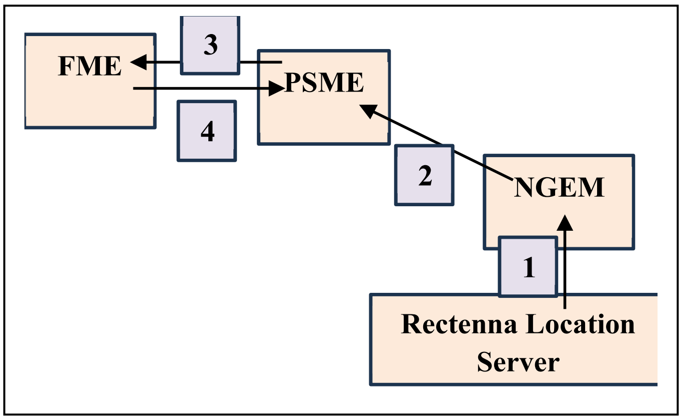

Fig. 1. Relations between the computing entities of the FME, PSME, NGEM and the Rectenna Location Server

B. Networking Architecture

The provisioning of power by the large-sized space-based power satellites requires the exchange of data between space-based power satellites. The operational frequency for the transmission of microwave power from the space based solar power satellite to the rectenna is one subject to the least atmospheric losses. An example of a suitable frequency range is (5.5–6.0) GHz [18]. In addition, the communication between transcetennas in the proposed system is also executed using the high frequency spectrum. In this case, the typical frequency used in conventional intersatellite links such as the range (5.25–5.875) GHz [19], [20] are utilized for the transmission of power between transcetennas when multiple large-sized space-based solar power satellites exchange power to meet remote power demand.

The choice of the spectrum in the range of 5 GHz – 6 GHz has been born of their suitability as recognized in existing work [18], [19], [20] ; and ease of satellite realization. In addition, the non-use of high frequency spectrum has not been considered due to the high free space path loss and the need to avoid interference with the Ka, K, and Ku bands that find significant applications in existing satellite communication applications. Furthermore, the choice of a lower frequency range in this case has the challenge of requiring a larger antenna size. The larger required antenna size in this case increases launch mass and costs. Furthermore, the spectrum of interest i.e., the 5.25 GHz – 5.875 GHz also has the benefit of being unlicensed. Therefore, the use of the concerned spectrum does not incur additional spectrum licensing overhead. The transmission of microwave signal experiences loss in the context of inter-satellite link communication and satellite to ground link related communications. The loss occurring in this case does not impact the amount of power deliverable as scheduled and incorporated into the satellite link budget.

From the perspective of communications i.e., power transmission, the proposed large-sized space-based solar power satellite functions in three modes. These modes are: (i) power supply mode, (ii) power forwarding mode, and (iii) data exchange mode. In the power supply mode, the large-sized space-based power satellite transmits onboard power to meet the energy demand associated with a given rectenna. This mode becomes active when the solar power satellite has a communication window with a given rectenna. The power forwarding mode becomes activated after the analysis of data by the PSME determines that the power onboard the solar power satellites is insufficient to meet the rectenna demand. Such a scenario arises given a large rectenna ground density i.e., a significant number of rectennas that are not significantly distant apart. The combination of a large rectenna ground density, high power demand and power constraint aboard the space power satellite are conditions that necessitate the transition to the power forwarding mode. In addition, the introduction of the data forwarding mode is crucial in the realization of the proposed space-based solar power network. This contrasts with the existing case such as that found in [21] where a network paradigm has not been considered in relation to space-based solar power satellite systems. Currently, constellation designs are only associated with the use deployment of optical space reflectors not systems associated with the use of space-based solar panels with the beaming of microwave signal (with power) as seen in [20], [22], [23], [24], [25]. The use of solar panels proposed in this case is more beneficial than the use of solar reflectors. This is because the use of solar reflectors requires the availability of solar panels at a given location. The requirement of a solar panel system pre-conditions the availability of a grid. This limitation does not affect the proposed case where the end-user is only expected to have a rectenna.

The consideration of a network paradigm implies an increase in the ability to ensure continuous power supply for each region hosting the rectenna. The continuous power supply in this case is realizable via the use of the forwarding transcetennas. The data exchange mode is one where the data on rectenna location is exchanged with the solar power satellites' NGEM. In the network architecture, the proposed space-based power satellite hosts computing capabilities enabling the execution of the functionalities in the NGEM, PSME, and FME. The relations between the modes involved in the solar power satellite's modes as envisaged in the networking architecture is in Figure 2.

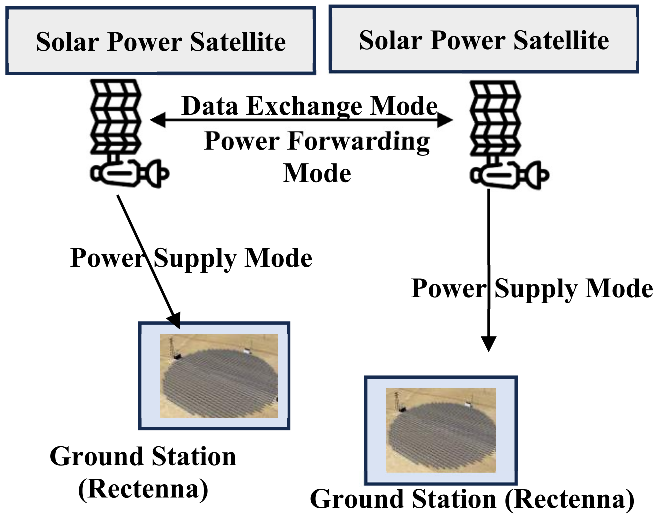

Fig. 2. Relations between the power supply, power exchange, and data exchange modes in the proposed approach.

C. Supporting Network Protocol

The use of the proposed ubiquitous large-sized space-based solar power satellite and network require the design of protocols that execute the functionalities in the power forwarding mode. The power forwarding mode enables the determination of route between transcetennas that enable remote power access. In this case, routing protocols that determine the shortest path and with the least power loss are desired. The routing protocol in this case does not essentially execute data forwarding but ensures that the smallest number of hops are executed. Each hop is associated with a finite power loss, and a large number of hops signify increased power loss. This implies the reception of a reduced amount of power at the requested rectenna. In addition, the choice of the minimum number of hops also enables the realization of a short latency in meeting the power demand at a remote rectenna location. In determining the route between all solar power satellites, a routing table is determined via the transmission of dummy packets. The transmission of these packets is executed in the data exchange model. This is done to determine the least hop path for different source to destination paths. This is done by each large-sized space-based solar power satellite. Therefore, each of the concerned satellite has its own routing table. The routing table is utilized in a hybrid approach. A hybrid approach is one where there is a central routing entity, and a decentralized routing entity. The central routing entity is a computing system that hosts the constellation routing table. The decentralized routing entity is a computing system that hosts the routing table for a given large-sized space-based solar power satellite. The centralized routing entity has more computing resources and power and is hosted in the central ground-based control facility. The decentralized routing table is updated at intervals from the network entries and observations from the network that are recorded in the central routing computing entity.

IV. Open Interface System Design

The focus of the discussion in this section is the description of the open interface design approach to the realization of the proposed solar power space-based network architecture. The perspective of an open interface design approach in this case is not device specific but network wide to enable interworking with multi-vendor large-sized space-based solar power networks.

An open interface design approach is deemed necessary to support the incorporation of multi-vendor large-sized space-based solar power satellites. The consideration of the need to support multiple vendors necessitates the realization of a standard to support the execution of the functions in the proposed large-sized space-based solar power satellites. Different vendors are expected to have different implementation of the critical components such as the: (i) Rectenna Location Server, (ii) NGEM, (iii) PSME, (iv) FME, and the (v) transcetenna. In addition, large-sized space-based solar power antennas are expected to be backward compatible with existing small satellite based solar power satellites. In this case, small satellite based solar power satellites are those that have previously been launched by space solar power providers.

The need for an open interface system design arises from the fact that different equipment manufactures will have varying information format for scenario representation, and message formation. This influences the format and inference that can be drawn in the data exchange mode, power supply mode, and the power forwarding mode. An open interface will enable the system to continue the main function of providing power to the rectenna in the power supply mode or via the transcetenna in the power forwarding mode.

The functionality of the implied format translation should be executed in each of the in-orbiting proposed large-sized space-based solar power satellites. This is done by the format translating entity (FTE), an entity that is incorporated into the computing payload of the proposed large-sized space-based solar power satellite. In executing its function, the FTE pre-uploaded the information on the format of data representation. This is achieved by requiring original equipment manufacturers to upload information format structure in a globally accessible repository. Each large-sized space-based solar power satellite is equipped with the capability to recognize a pre-specified number of information representation formats. It checks for the format of the field structure of the received information with a pre-uploaded information representation format. The successful recognition of the format enables the successive execution of scenario inference, decision-making, and reconfiguration.

The role of the implied format translation in meeting power deficit at a high-power demand ground location is presented in the following manner. The concerned scenario is one comprising multiple large-sized space-based solar power satellites in a low earth orbiting constellation. There are three satellites in this case i.e., Sat 1, Sat 2, and Sat 3. Each of the satellites have different original equipment manufacturers (with own information formats). In the considered scenario, the satellites i.e., Sat 1, Sat 2, and Sat 3 provide beamed microwave signal to a given ground location GND 1. Sat 1 is the first satellite with which the ground station at GND 1 has a coverage window. However, Sat 1 is not able to meet the high-power demand at GND 1. Therefore, it is necessary to communicate with either Sat 2 or Sat 3. In the considered scenario, only Sat 2 has an FTE capacity and is able to meet the power demand at GND 1. This results in a power deficit at GND 1 though there is a significant amount of power available on Sat 3. In the case of the scenario considered, the non-availability of the FTE capacity on Sat 3 implies that the concerned satellite has limited ability to reconfigure in providing power to the concerned location i.e., GND 1. Essentially, the satellite Sat 3 is unaware of the power deficit due to its inability to meaningfully communicate with Sat 1.

V. PERFORMANCE INVESTIGATION

The discussion in this section has two aspects. The first aspect focuses on performance formulation. The second aspect focuses on the investigation of the performance benefits.

A. *Performance Formulation and Modelling*

The performance formulation considering the ability of a constellation of space based solar power satellites to meet the power demand of a region is considered. The considered region is one without grid coverage but requires access to power. Let the set of space-based solar power systems i.e., satellites be denoted as α.

$$\alpha = \{\alpha_1, \alpha_2, \dots, \alpha_M\} \tag{1}$$

The power aboard the m^{th} satellite $\alpha_m, \alpha_m \epsilon\, \alpha$ at the epoch $t_y, t_y\ \epsilon\, t, t =\ \{t_1, \dots, t_Y\}$ is denoted as $P_1(\alpha_m, t_y)$. In addition, the communication indicator enabling information translation between satellites $\alpha_{m+1}, \alpha_{m+1}\, \epsilon\, \alpha$, and α_m at the epoch t_y is denoted $I_A(\alpha_m, \alpha_{m+1}, t_y)\, \epsilon\, \{1,0\}$. Space-based solar power satellites α_m, and α_{m+1} can and cannot communicate with each other in the scenario described as $I_A(\alpha_m\ ,\ \alpha_{m+1}, t_y) = 1$, and $I_A(\alpha_m, \alpha_{m+1}, t_y) = 0$, respectively. In this case, the concerned communication arises via the presence of inter-satellite links and in the absence of the proposed FTE. The inclusion of the proposed FTE increases the communication ability between space-based solar power satellites arising from different original equipment manufacturers.

The identified benefit arises due to the role of the repository associated with the proposed FTE. In this case, the FTE availability indicator between the satellites $\alpha_{m+2}, \alpha_{m+2}\, \epsilon\, \alpha, \alpha_{m+1}$, and α_m at the epoch t_y is denoted $I_A(\alpha_m, \alpha_{m+1}, \alpha_{m+2}, t_y)\, \epsilon\, \{1,0\}$. The space-based solar power satellites α_m, α_{m+1}, and α_{m+2} though belonging to different network operators and arising from different original equipment manufacturers are able to communicate in the scenario described as $I_A(\alpha_m, \alpha_{m+1}, \alpha_{m+2}, t_y) = 1$. In the scenario described as $I_A(\alpha_m, \alpha_{m+1}, \alpha_{m+2}, t_y) = 0$, not all the concerned satellites (belong to different network operators and arising from different original equipment manufacturers are not able to communicate at all epochs. This is because of the non-ideal behaviour or limited capability of the proposed FTE in this case.

Given that the power demand at the considered location is denoted P_2, the power deficit without (existing case such as that in [21]) is denoted P_{def}^1 and given as:

$$P_{def}^1 = P_2 - A_1 \quad (2)$$

$$A_1 = \sum_{p=1}^{P}\sum_{q=1}^{Q}\sum_{y=1}^{Y}\left(P_1(\alpha_p, t_y) + P_1(\alpha_p, t_y)\right) I_A(\alpha_p, \alpha_q, t_y) \quad (3)$$

$$P + Q \leq M \quad (4)$$

In the proposed case, the power deficit is denoted P_{def}^2 and given as:

$$P_{def}^2 = P_2 - \sum_{i=1}^{2} A_i \quad (5)$$

$$A_1 = \sum_{p=1}^{P}\sum_{q=1}^{Q}\sum_{y=1}^{Y} P_1(\alpha_p, t_y) I_A(\alpha_p, \alpha_q, t_y)\, p + q = M \quad (6)$$

$$A_2 = \sum_{p=1}^{P}\sum_{q=1}^{Q}\sum_{s=1}^{S}\sum_{y=1}^{Y}\left(P_1(\alpha_p, t_y) + P_1(\alpha_q, t_y) + P_1(\alpha_s, t_y)\right) I_A(\alpha_p, \alpha_q, \alpha_s, t_y) \quad (7)$$

$$P + Q + S \leq M \quad (8)$$

B. Performance Investigation and Analysis

The results of performance evaluation and performance benefits of using the proposed approach are presented in this aspect. The performance evaluation parameters for the modelled scenario are shown in Table 1. The parameters presented in Table 1 concern the case of a constellation of solar interception satellites. The power values in this case are those associated with that received at the ground station. In this case, the power output from the solar interception satellite exceeds those shown. The performance evaluation has been done in this manner considering that each of the concerned satellite has an incorporated link budget. In addition, the simulation has considered a highly directional beam between the solar interception satellite and the concerned ground station.

In addition, the ground stations are deemed to require an energy supply of 1.9MW and are located in a region without grid coverage due to significantly unfriendly terrain. Such a case can also arise in the aftermath of a natural disaster that has destroyed all the previously existing grid infrastructure. The solar intercepting satellites in this case comprise intersatellite links with and without the proposed FTE capacity. The proposed FTE capability enables the increased use of intersatellite links effectively between satellites arising from different original equipment manufacturers.

Table 1: Performance Evaluation Scenario Parameters

S/N	Parameter	Value
1	Energy Required at Terrestrial Location	1900 kW
2	Number of Satellites	10
3	Minimum Power Output from Satellite	11.9732 kW
4	Mean Satellite Power Output	529.9732 kW
5	Maximum Satellite Power Output	1191.5 kW
6	Number of Active Intersatellite Links	28
7	Number of Inactive Intersatellite Links	20
8	Number of Active FTE related links	27
9	Number of Inactive FTE related links	17

The performance evaluation results showing the power deficit (MW) for the existing case [21], and proposed case is shown in Figure 3. The results presented in Figure 3 show that the use of the proposed case reduces the power deficit for the concerned location. From Figure 3, it can be seen that the activation of the proposed FTE based solution in six satellites results in a reduction in the power deficit. Further analysis shows that the use of the proposed approach instead of the existing approach reduces the power deficit by an average of 17.85%.

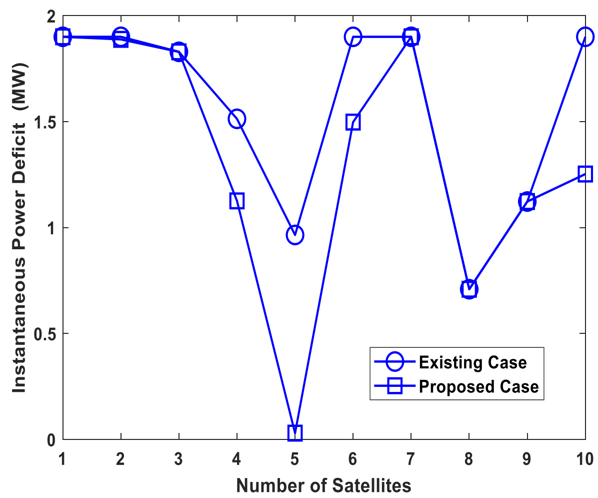

Fig. 3. Performance Evaluation Results

VI. CONCLUSION

The research proposes the use of space-based solar power networks to enable the realization of ubiquitous power provisioning. It also proposes the use of large-sized space-based solar power networks as integral space assets in the space-based solar power networks. The large-sized space-based solar power satellite is recognized to be suitable due to an observed re-emergence of large sized space assets following the long-term use of low-cost small satellite systems. The research also presents the architecture of the proposed large-sized space-based solar power system with a focus on describing the computing and networking architecture aspects. The proposed architecture of the large-sized space-based solar power satellite introduces the capacity of a power signal forwarding transcetenna, an inter-satellite link related functionality enabling the forwarding of power signal between space-based solar power satellites. The introduction of this capability is intended to achieve ubiquitous coverage to enable remote power transitioning via the space-based solar power network constellation. In addition, the research identifies and discusses the need to achieve open system interface design and integration. This is deemed important to ensure the large-sized space-based solar power networks are able to work with other space assets in the proposed architecture and solution. Future work will focus on exploring the prototype design related studies and examining the execution options for the realization, and operation of the proposed large-sized space-based solar power network. In addition, the realized prototype will be used to validate the performance benefits of the proposed solution.

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