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UNDERSTANDING THE FACTORS OF SERVICE SUPPLY CHAIN IN THE INDIAN POWER INDUSTRY

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Abstract

The services of the smart grid are intended to improve grid observability, asset controllability, performance, and security as well as financial elements of operations, maintenance, and planning. The purpose of this study is to identify the factors related with service supply chain of smart grid, identify the most significant service variable, and then understand the importance of it in service level of smart grid. This study has identified 16 relevant influential factors that initiate the service supply chain management (SSCM) for representing the possible interrelation among the identified factors. A TISM approach is used to illustrate how these service factors are interrelated by systematically handling expert views and helps to chronologically assemble various factors from the greatest importance to the slightest least importance ones. Further, these factors are grouped using the MICMAC study grounded on their driving and dependence power. This research provides a complete thoughtful on directional interrelationships between the service components factors and delivers the best possible solution for the active operation of the smart grid and its performance. The ESS system is identified in the current study as the essential element that must be incorporated into the smart grid in order for the electricity grid to operate effectively. This study gives an insight into the current energy scenarios of India, potential, initiatives, and policy regulation. Thus, the proposed model, considered as unique research to understand the fundamental services for efficient performance of smart grid. This study adds significantly to the literature on the energy sector by capturing the perspective of various stakeholders.

Keywords: Service components, TISM (Total Interpretive Structural Modelling), Driving Power, Dependence Power, Cross-impact matrix multiplication applied to the classification analysis(MICMAC).

1. INTRODUCTION

Since the world economy has become more and more service oriented, services have drawn a lot of interest in the customer satisfaction, service modelling and design and improvements in the critical components of service delivery. For instance, it is stated that the service industry contributed more than 90% of the GDP in industrialized nations like the US. The service sector is expanding quickly worldwide, even in developing nations like the BRICS (Brazil, Russia, India, China, and South Africa). As a result, many estimates state that services would eventually dominate the global economy (Arnold *et al.,*2011). Services are essential to supply chain management systems. In service supply management, customer service is a key concern. Industries including IT and telecommunications, power, banking, and logistics have been extensively studied in the OR literature about service supply chain management. India is a big nation that is dependent on electricity to a large extent, like in the agricultural sector, big manufacturing agencies, etc. Nowadays, the electricity industry is facing increasing pressure from consumers, businesses, and governments to provide new ways to increase energy efficiency (Corbett, 2013). Concept of Smart Grid design is aimed for grid observability, create controllability of assets, enhance performance and security of power system and specially the economic aspects of operations, maintenance, and planning.

The smart grid services industry is an important industrial sector. All aspects of the electricity supply chain are being affected by smart grid technologies, which are also bringing forth advances in the electrical power sector. Smart grid technologies are bringing innovations in electrical power industries, affecting all parts of the electricity supply chain, and leading to changes in market structure, business models and services. These innovations are changing the market structure, business models, and services A smart grid is a comprehensive information architecture and infrastructure system that addresses every aspect of the value chain for electricity, including electrical networks, transmission, and generation (Li et al.,2013). It enables the optimization of electricity delivery and bidirectional communication between the system operator and grid users.

Currently, there is a huge production in the automotive industries and energy consumption resulted into spike in the cost and emissions of greenhouse gases. Hence, an efficient energy utilisation mechanism has become a prime most important factor. Energy and its conservation problem also have raised and become one of the prominent critical factors needed to address. Therefore, the development of smart grid infrastructure is one of the solutions to address the above issue. Another driving reason for India to implement smart grid services is the ageing and inefficient transmission network.

Numerous studies on the evaluation of smart grids have been undertaken in recent years as smart grid technology have developed. The goal of this paper is to evaluate the prior research and approaches pertaining to the integration of various service components in smart grids. There are limited studies which focus on analyzing the overall issues faced by smart grid supply chain and service-oriented architecture for smart grids in Indian transmission grid. Identification of most significant factor for development of service-oriented architecture for smart grids was limited. Also, there are limited studies in the Indian context that provide a qualitative evaluation of smart grid services in the power grid, deployment objectives, and procurement techniques in the Indian power system. It is crucial to identify the key factors responsible for service supply chain of smart grid to improve the effectiveness of power grid. The authors have thus conducted a thorough analysis to identify the essential factors for service supply chain of Smart Grid and establish hierarchical inter-relationships among them.

The research objectives were defined as follows:

RO 1: To identify the factors responsible for service supply chain of Smart Grid.
RO 2*:* Model these factors to establish hierarchical inter-relationships among them and present the role of energy storage system in Smart Grid
RO 3**:** To analyze these factors on the basis of their driving and dependence power

This paper will lay out the introduction on the factors that are pulling and pushing the utilities to change the way they operate in order to improve the current services. The first objective is achieved by reviewing papers in the Scopus database and communicating with academicians and power industry managers to identify various service components factors responsible for service supply chain of smart grid. This study has identified 16 relevant influential factors that initiate the service supply chain management (SSCM) for representing the possible interrelation among the identified factors. The next step is to analyse and develop approaches for curtailing their influence. It is accomplished by using TISM (total interpretive structural modelling) methodology. The second objective is accomplished using the TISM approach, which establishes inter-relationship between the factors of smart grid service variables and examines direct, indirect relationships and logical interferences to give a reason behind the authenticity of the relationship between any two factors. TISM provides the following advantages: (1) This will categorize the service variables into four categories i.e., strategic, tactical, operational, and performance factors, where strategic factors are drivers' factors and performance-based factors are dependent variables. (2) It develops a framework in the hierarchical model to investigate interrelationships among the identified factors. (3) It provides extensive opportunities to go through the judgments by policymakers' representatives to make up-to-date decisions identified in the overall service chain of smart grid system. Further, these factors are clustered using MICMAC analysis grounded on their dependence and driving power. This research gives possible ways to run the future smart grid supply chain in an efficient secure and reliable manner. The results shows that Energy storage is pinpointed as a key technological component that can transform the current structure and operation of the power grid . This research explains how a unified battery management system is an important part in building a smart grid environment and discussed the role of ESS in service management layer of proposed approach. This study gives an insight into the current energy scenarios of India, potential, initiatives, and policy regulation, including the potentialities of renewable energy sources to achieve sustainability in energy to meet the sustainable development goals. The paper is organised as follows. In section-2 background of smart grid services and its service supply chain of smart grid is explained in detail. Section 3 deals with the literature review of services factors responsible for providing efficient service to the smart grid. Section 4 explains about the research methodology of TISM and MICMAC in detail. In section 5 the proposed methodology is explained with the help of identified problem. Section 6 includes the result and discussion section. In section 7 managerial implications are given. And lastly conclusion and future scope is mentioned.

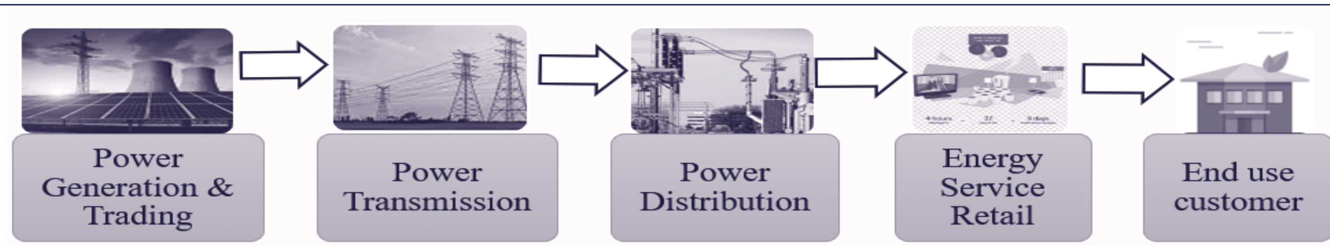
2. BACKGROUND AND IMPORTANCE OF THIS STUDY

The SG infrastructure is the backbone of the future smart cities and the connected electric mobility. Smart grid is termed as the next-generation energy networks, which integrate distributed generators (DGs), renewable energy resources (RES), controllable loads, smart sensors and advanced metering infrastructure to enable two-way digital communications between utilities and their customers (Tuballa and Abundo 2016). Smart Grid as a Service certainly not for everyone. Some utilities are already too far down the path to take a different approach. Some have already made the difficult internal investments required to transform themselves into nimble, effective, and mature IT and security operations that get the most out of their investments. However, for those who seek to maintain focus on core functions and staff, and are looking for a more rapid, fit-for-purpose, and cost-effective smart grid transformation, Smart Grid as a Service has begun to catch the attention of cost-conscious and focused utilities. Instead of utilities becoming large IT organizations, some utilities are choosing to focus on their core mission, and engaging partners whose core mission is operational excellence in smart grid critical infrastructure operations and security.

2.1 Smart Grid Services: Indian energy sector also benefits by technological innovations, operations cost optimization, competitiveness, and variety build-up. Smart Grid is an Electrical Grid with Automation, Communication and IT systems that can monitor power flows from points of generation to points of consumption (even down to appliances level) and control the power flow or curtail the load to match generation in real time or near real time. Grid services includes all instruments that control the access to a grid system, including laws and regulations that control energy connection, transmission, and distribution and other ancillary services (Leonhardt et al., 2022). Smart Grid as a Service is allowing utilities to externalize the technological distractions and focus on improving core operations through dependable mission critical smart grid intelligence. Smart grid as a Service reduces the utility's challenges associated with IT but does not confuse IT with energy operations. Smart grid is the intelligent integration of distribution, transmission, generation for the efficient delivery of secure, sustainable, and economic electricity. As the grid becomes more intelligent and more complex, the tools to operate it become increasingly important. To be useful, however, those tools must be fully integrated. It enables various smart and automatic applications such as smart metering infrastructure supported by bi-directional data flow (Ivanov et al., 2013; Cagno et al.,2018; Faheem et al., 2018), smart distribution system (Tuballa and Abundo (2016)), RE integration (Al-Shetwi et al.,2020), Energy storage integration(Suberu et al.,2014); automatic demand response (Xue et al., 2014), integration of electric vehicles (Ahmad et al.,2017), cyber security (Zhuang et al., 2020), smart meters (Zanghi et al., 2019) .

Development of smart grid is to facilitate new business model, promote consumer's active participant and develop a sustainable system by integrating advance technologies, utilizing researchers, and skilled workers in order to provide secure, efficient and sustainable system. Actors in the utility domain perform services to support the business processes of power producers, distributors and consumers. The utility domain shares interfaces with the operations, markets and consumer domains. Communications with the operations domain are vital for situational awareness and system control, communications with the consumer and markets domains are vital for enabling economic growth through the development of "smart" services. Utilities will produce new and innovative products and services to meet the new necessities and opportunities presented by the evolving Smart Grid. All of the services and innovations that have yet to be created. These will be instrumental in defining the Smart Grid of the future.

2.2 Service Supply chain of Smart Grid: Electricity supply chain includes companies that operate in the fields of generation, transmission, distribution, and consumption of electric energy (Figure 1). As the smart grid develops, the new business models arise, new companies appear on the market and the supply chain becomes more complex. Therefore, smart grid companies need new supply chain intelligence systems that integrate business elements, concepts, tools, and smart grid technologies. It presents the various components of smart grid technologies, the application and the role of different tools in implementing the smart grid, its functions, needs, characteristics, and opportunities in this domain. The elements of a smart grid supply chain determine the necessity for business intelligence tools and techniques. The main domains in a smart grid supply chain are:



Generation domain is responsible for generating electricity for delivery to consumers. The transmission domain is usually the boundary of the generation domain. The bulk generation domain is connected to the transmission domains electrically and shares interfaces with the markets, operations, and transmission domains. Communications with the transmission domain is most important because without transmission, consumers cannot be served. The bulk generation domain should communicate main performance and quality of service issues such as scarcity and generator failure.

Transmission domain is responsible for the bulk transfer of electrical power from generation station to distribution system through multiple substations. A transmission network is normally operated by an RTO or ISO whose primary responsibility is to maintain stability on the utility grid by balancing supply (generation) with demand (load) across the transmission network.

Distribution domain comprises of components which provides electrical interconnection between the transmission domain, the consumer domain and the metering points for consumption, distributed storage and DG. The distribution system can be arranged in a variety of structures, including looped, radial or meshed.

Customer domain: Residential, commercial and industrial customers are the end users of electricity. They also have a possibility to produce and distribute energy if they possess an electricity source, such as solar panel or a windmill, and therefore influence the retail market competition.

Utility domain: shares interfaces with the operations, markets and consumer domains. Customer service and relationship management are becoming more important for electricity utilities operating in deregulated markets**.** Smart grid technologies, including the tools for intelligent network management and performance monitoring have spurred a worldwide demand for further research on how advanced analytics can help electricity utilities to better track grid operations Lukić et al., (2017). Concerns about the deployment of smart grids services, including as high investment costs, the necessity for infrastructure development, smart appliances, and demand management, were cited as significant impediments to smart grid development. Table 1 explain the service supply chain of smart grid. It help to determine the service components, services offered and actors involved in each stage of supply chain of whole smart grid in brief.

Table 1. Service supply chain of smart grid

Supply chain of Smart Grid	Power Generation ⟶	Transmission ⟶	Distribution ⟶	Retailer ⟶	Consumer
Services offered	Generating electricity for delivering to consumer	Bulk transfer of electrical power; Cybersecurity	Provide interconnection between the transmission domain, consumers & metering point for consumption; Cybersecurity; Balance energy demand & supply	Facilitate real-time monitoring and control	Utility applications; efficiency and reliability; Cybersecurity; Reduce utility bill and generate revenue;
Service Components	Smart generation; Renewable Energy Source (RES) integration; Energy storage system (ESS)	ICT integration; Sensing and measurement;	ICT integration. Distributed power generation; distributed grid management; RE &ESS integration	Energy market; ICT integration, Demand response utility rates;	Smart Meters and building automation; customer engagement
Actors Involved	Energy producers,	TSO, Industry, service company	Distribution System Operator (DSO) business industry, distributors of electricity to and from customers.	Utilities; Sub-station controllers; Organization providing services to customers	Residential, Tertiary; Industry

3. LITERATURE REVIEW

This section summarises the literature review on service supply chain of smart grid and factors responsible for efficient services in smart grid. The concept of the smart grid evolved from prior attempts to monitor and regulate power system through the use of different service components such as: distributed generation or smart generation; RE integration, energy storage system, bi-directional ICT infrastructure, smart metering, sensors, cyber security; automatic demand response; dynamic pricing**.** The main service components in a smart grid supply chain are explained below:

3.1 Service Supply chain of smart grid**:** The basic concept of the smart grid supply chain and its effect on the electricity market stakeholders are outlined together with the conceptual model described by National Institute for Standards and Technology (National Institute for Standards and Technology NIST, 2012). This model shows interconnected communications across the smart grid and provides a framework for identifying actors, communication networks, interactions and their potential capabilities (IEEE Smart Grid, 2014). Services play a crucial role in supply chain systems. Customer service is a central topic in service supply management. There are a number of studies that review and discuss different definitions of service supply chain systems and service supply chain management. In a supply chain system, by definition, there must be a "product" that is created by "the points of origin" and delivered at "the points of consumption". This "product" can be a tangible physical product or a service product. In a service supply chain, it is important for every supply chain member to take care and work with other members in the system. Thus, coordination is essential in-service supply chain management. In service supply chain management, industries such as IT and telecommunications, electricity, finance, and logistics have been popularly examined in the OR literature. One important industrial sector is the smart grid services industry.

3.2 Factors responsible for efficient service supply chain of Smart Grid: The grid should also be able to handle the various services and information within the grid network and analyse them efficiently to provide the optimum output to the system. Thus, it is very much essential to know about each of service components and infrastructure details to have a clear idea about the working about the SG connected network.

3.2.1 Government Support (F-1): Governments and the various instruments of government, from GHG reduction targets and energy distribution regulations to fiscal incentives for investment in renewables, play an important role in shaping energy transition and in the establishment and viability of community energy initiatives. In India, RE procurement has been led mainly by central government organizations i.e. by SECI (Solar Energy Corporation of India) and NTPC Ltd., with some assistance from state government agencies (Chawla et al., 2020).

3.2.2 Regulations & Standard (F-2): The Government of India has formulated many policies and subsidies to encourage the installation of microgrid. The regulatory framework of the electricity industry is encouraging more smart solutions that typically rely on the active participation of customers in DR in order to mitigate both social and capital costs (Hossain et al., 2016). However, the updated policy has improved the electricity market's openness, adaptability, and competitiveness by providing a more effective regulatory framework (IqtiyaniIlham et al., 2017).

3.2.3 Top Management Support (F-3): Top management support (TMS) is one of the *critical success factors that affect performance of projects* in organizations. The top management/stakeholders' support and commitment can ensure the organisation's communication of sustainability policies and goals. It is necessary to have TMS as it helps to enhance work flexibility, which could improve the organization's productivity, profitability, and performance. Leadership by top management was mentioned consistently by utilities that have advanced farthest in smart grid adoption (Dedrick et al.,2015). One manager argued that the kinds of organizational changes required can only be made through top-down mandate.

3.2.4 Capacity of Service Provider (F-4): Service providers provide services to a large number of users. Service providers must be able to find a way to monetise the market. Service provider, and a regulatory framework provides incentives for investment in power management or more traditional forms dependent on what is best for the power sector (Faerber et al., 2018). Service providers provide customer management, billing, installation, and maintenance in overall grid system. Their capacity allows an electric company to remotely monitor, manage, and coordinate the distribution components placed in a substation network.

3.2.5 Financial Strength (F-5): Financial supports are the most frequently discussed component in the literature on energy services towards grid. Several authors discuss the importance of loans provided by governments or state-owned banks as essential financial instruments to support community energy. When determining the viability, industrial and commercial acceptance of new technology, its capital cost is a critical factor (Akinyele and Rayudu, 2014). Smart grid deployment involves investments and growth throughout the electricity value chain, particularly among consumers (Park and Heo, 2020). It includes nation's capacity to pay development cost for smart grid infrastructure (Butt et al., 2021).

3.2.6 Technical interventions (F-6): The grid upgradation has resulted in new market structures, services, and societal processes. Industries need to make strategies for investment and deployment of smart grid technology to substitute the conventional grid in a time bound and phased manner. Khan and Haleem (2008) concluded that technological and human capacities are essential to any organization's process of absorbing new technologies. Companies within and outside the conventional electric industry are developing and commercializing technological innovations to provide technical solutions to utilities and consumers.

3.2.7 Infrastructure Development (F-7): Infrastructure development is vital issue in smart grid communication. The grid infrastructure has played a critical role in making power sector smarter. The transition from traditional centralized architecture to distributed one is therefore necessary. For providing efficient service to mobility, it is essential to have an efficient architecture. Adoption of smart grid technologies involves new assessment routines using evolving information and communication technology, which can support the recognition of technical issues and the improvement and customization of infrastructure (Zheng et al., 2018).

3.2.8 Competitiveness in market (F-8): Competitive market mechanisms in the field of power generation should be considered the main direction of power industry reforms. Energy players require information to offer a foundation for a competitive market and enable smart grids to reach maximum efficiency (Clastres, 2011). The new technology is viewed as an extra resource available to states for achieving goals such as enhancing competition, improving the safety of energy infrastructure, and mitigating climate change. Smart grids may foster competition through new offers and end-user pricing.

3.2.9 Electricity generation & grid integration (F-9): According to Al-Shetwi et al., (2020), grid integration is concerned with integrating renewable energy, distributed production, energy storage, and demand response into the transmission and distribution networks of electricity. Local energy generation can reduce the energy consumption cost, emission of harmful gases (as renewable energy sources are used to generate energy at user's premises) and increase the smart grid resilience.

3.2.10 Distributed generation (F-10): The rapid integration of RES and distributed generation has opened new opportunities for the Indian power sector to redefine its existing operational and business models. Tuballa and Abundo (2016) mentioned that distributed energy resources are small sources of power that can help meet regular power demand and very much important for efficient supply to customers. The distributed generators can help mitigate the problems of depleting fossil reserves and the growing consumer demand.

3.2.11 ESS/BMS Distributed Energy storage system (F-11): Energy Storage System (ESS) complementary in meeting the goals of an efficient smart grid. Energy storage can provide a "shock absorber" for the overall grid system (Zame et al., 2018). It is pinpointed as a key technological component that can transform the current structure and operation of the power grid. ESSs are utilised in the electric power sector for a variety of purposes, including RE exploitation, commodity arbitrage, transmission assistance, distribution deferral, power quality, DG support, and off-grid electricity delivery. ESS will be critical in fulfilling energy demands by enhancing the grid's operational capacities and reducing infrastructure expenditures. ESS can handle transmission and distribution concerns while simultaneously managing the quality and reliability of electricity provided by conventional and variable energy sources.

3.2.12 Cybersecurity (F-12): Cyber security is a critical issue for developing smart grids and the energy revolution. Various research efforts have focussed on the security and privacy concerns arising from the introduction of smart energy meters. Power theft that is a common problem in India due to little protection of grid and high poverty rate. Zhuang et al. (2020) recommended the use of blockchain technology to support the operation and development of the smart grid and strengthen the smart grid's resistance against cyber attacks. Consequently, security will be provided from the smarter device through the utility's central processing unit to smart grid technologies.

3.2.13 ICTs Bidirectional communication (F-13): ICT systems have become a vital part of every aspect of our daily lives and its integration into the electric power system has become paramount. ICTs support efficient incorporation of activities of all stakeholders of the power system to certify a more cost-effective and sustainable power system (Jimada and Teh, 2020). It will build a highly reliable and flexible communication infrastructure and allow protocols to enable real-time interactions between producers and consumers in the smart grid system (Faheem et al, 2018).

3.2.14 Dynamic pricing (F-14): Revenue management and dynamic pricing are concepts that have immense possibilities for application in the energy sector. Both can be considered as demand-side management tools that can facilitate the offering of different prices at different demand levels (Soni and Mukherjee 2018). Dynamic pricing plays an important role in modern smart grid system in solving problems such as congestion control, peak load reduction, energy management of traditional grid in cost-effective manner. Dynamic pricing can shift the demand from peak to off-peak and help avoid large capital investments, which in turns provide high return on investment.

3.2.15 Automatic demand response (F-15): Demand response (DR) will play a vital role in the development of future power grid. It facilitates the reduction of power consumption and saves energy. Demand response is an emerging application of smart grid in exploiting timely interactions between utilities and their customers to improve the reliability and sustainability of power networks (Shi et al., 2021; Tuballa and Abundo 2016). Demand response provides consumers a chance to be involved in grid operations as they can reduce or shift their electricity usage during peak periods and benefit through financial incentives. Demand response (DR) is an effective and efficient tool or a set of activities to improve electric grid reliability, manage electricity costs, and ensure that customers receive signals that encourage load reductions.

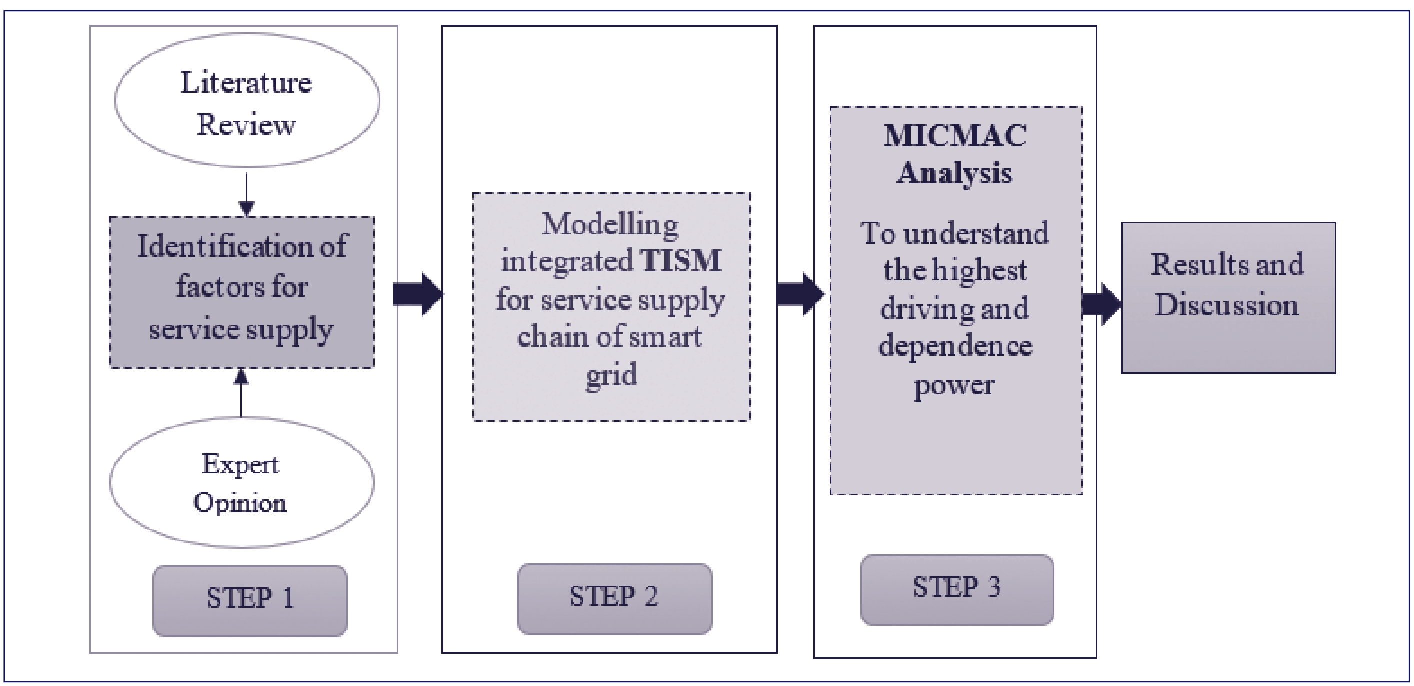
3.2.16 Return on Investment (F-16): The smart grid deployment requires investment and development that concern the entire electricity value chain, and especially within the electricity consumers' domain (Samad and Kiliccote 2012). According to Farhangi (2009), ROI grows with the increasing functionality of the smart grid. The implementation of energy flexibility solution depends on Savings, profit, Investment and payback time (max 2 years) for implementation of a new energy saving solution.

4. RESEARCH METHODOLOGY

This section describes an integrated methodological approach to assess and estimate the service supply chain of smart grid to get maximum return on investment in the electricity sector. The technique employed in the current study is included in this part, along with the research framework and identification of service factors.

4.1 Research framework for current research: The entire schematic flow of this research is illustrated in Figure 2. It comprises of three steps: Firstly, identification of factors for service supply chain of smart grid. Secondly, TISM (Total Interpretive Structural Modelling) methodology is processed, here, TISM establishes the inter-relationship between the service components of smart grid and model the direct and indirect relationship alongside their logical interferences. Lastly, MICMAC analysis is done for graphical representation to understand the highest driving and dependence power in service supply chain of smart grid.

Figure 2. Schematic flow of research



4.2 Identification of factors for service supply chain of smart grid: In this study, we identify 16 crucial service factors of smart grid's service supply chain for efficient performance of grid. Table 1 represent the complete list of service factors by studying the past literature and expert opinion. These 16 service factors have been divided into four levels: strategic, tactical, and operational level service factors. This section describes an integrated methodological approach to assess and estimate the service supply chain of smart grid to get maximum return on investment in the electricity sector. The technique employed in the current study is included in this part, along with the research framework and identification of service factors.

Table 1. Service factors of smart grid supply chain

Sr. No	Factor	Description	References
1	Government Support (F-1)	GoI is making efforts to initiate different strategies to widespread implementation of smart grids to meet future energy demand in reliable and efficient way.	Rekha (2019).
2	Regulations & Standard (F-2)	One factor influencing innovation adoption by firms in many industries is the policy and regulatory environment. The updated policy has improved the electricity market's openness, adaptability, and competitiveness by providing a more effective regulatory framework	Zhu e t al.,(2004), IqtiyaniIlham et al., 2017).
3	Top management Support (F-3)	Leadership by top management was mentioned consistently by utilities that have advanced farthest in smart grid adoption.	Dedrick et al.,2015
4	Capacity of Service Provider (F-4)	Provide support services to all the stakeholders involved in generation, transmission, and distribution of electric power.	Butt et al., (2021).
5	Financial Strength (F-5)	Financial strength must include nation's capacity to pay development cost for smart grid infrastructure.	Akinyele and Rayudu, 2014; Park and Heo, 2020; Butt, et al., (2021).
6	Technical interventions (F-6)	Technical intervention of DES, IoT and ICT infrastructure in the smart grid brings the evolution of the networking roadmap.	Khan and Haleem (2008); Kumar and Pindoriya, (2020)
7	Infrastructure Development (F-7)	Infrastructure development is vital issue in smart grid communication. The transition from traditional centralized architecture to distributed one is therefore necessary. For providing efficient service to mobility, it is essential to have an efficient architecture.	(Zheng et al., 2018)
8	Competitiveness in market (F-8)	Utilities that faced competition, particularly in retail sales, were more motivated to adopt innovations to gain a competitive advantage.	Dedrick et al., 2015).
9	Electricity generation & grid integration (F-9)	Integration is concerned with integrating renewable energy, distributed production, energy storage, and demand response into the transmission and distribution networks of electricity.	Al-Shetwi et al., (2020),
10	Distributed generation (F-10)	DER systems may be linked to the local power grid or operated independently of it in stand-alone applications.	Tuballa and Abundo (2016)
11	ESS/BMS Distributed storage system (F-11)	Energy Storage Systems (ESS) will be critical in fulfilling energy demands by enhancing the grid's operational capacities and reducing infrastructure expenditures. ESS can handle transmission and distribution concerns while simultaneously managing the quality and reliability of electricity provided by conventional and variable energy sources.	Suberu et al., 2014.
12	Cybersecurity (F-12)	Cybersecurity is imperative for information infrastructure and the secure, reliable, and efficient operation of the smart grid.	Mohammed, A., & George, G. (2022, March).
13	ICTs Bidirectional communication (F-13)	the role of ubiquitous information and emerging ICTs infrastructure is very important for the realization of smart grid innovation.	El-Hawary, M. E. (2014).. Faheem et al, (2018).
14	Dynamic pricing (F-14)	Demand Pricing is considered as demand-side management tools that can facilitate the offering of different prices at different demand levels.	Soni and Mukherjee, (2018).
15	Automatic demand response (F-15)	Automatic Demand Response is an approach to demand side management that aims to influence the operation times of appliances. Demand response is a system through which a utility may remotely reduce the load on a customer's premises or disconnect specific customer equipment from the utility's control centre.	Xue et al., (2014)
16	Return on Investement (F-16)	It is a profitability metrics used to evaluate how well and investement had performed.	Samad and Kiliccote 2012; Farhangi (2009),

4.3 Methodology: TISM and MICAMAC are different methods used to achieve the set objectives. TISM develops mutual interaction between the service factors and offers a comprehensive interpretation to examine how one service influences another service in supply chain of smart grid. Next, MICMAC analysis helps to categorize all the service components into four categories i.e.. Driving, dependent, linkage and autonomous service components.

4.3.1 Development of Questionnaire: To achieve maximum operational efficiency of smart grid to get highest return on investment in the electricity industry, the questionnaire was created to gather respondents' thoughts on the significance of service factors for efficient supply chain of smart grid. The initial factors utilised in the survey were taken from the existing literature. Eight experts were used in a pilot study to assess the effectiveness of the questionnaire (2 from the power industry, 2 from central electrical authority, 2 from energy storage industry, and 2 from academics). The questionnaire had some further revisions after being discussed with experts.

4.3.2 Data collection: The modified questionnaire was then distributed to 16 corporate executives, senior government officials, and academics who operate in India's electricity service sector. The questionnaire was delivered through email. Additionally, reminder emails and, in some circumstances, calls were made. Of these 16 personnel, 4 were employed by the public sector, 5 by the private sector, 2 by the government and other organisations, and 5 by academic institutions. Maximum of the total respondents had experience more than fifteen years.

4.3.3 Total interpretive structural modeling (TISM): The most recent advancement in interpretative structural modelling (ISM) is TISM (Shankar et al., 2018), an improved qualitative modelling approach. Utilizing TISM, models of various systems are transformed from ambiguous and poorly articulated rational models into models that are clear, straightforward, and well-defined (Sushil, 2018). Utilizing TISM, where links are interpreted with the use of a tool known as a "Interpretive Matrix," one of the key drawbacks of ISM may be avoided, namely the poor interpretation of links and neglect of all transitive linkages in a digraph. TISM may therefore interpret the linkages and nodes in a structural model. The "what," "why," and "how" of theory development may all be explained using the decision modelling approach known as TISM. Researchers have used TISM extensively to model the components of several complex sectors, such as the ecosystem for the manufacture of smartphones (Jena et al., 2017), barriers of battery integration in grid (Gupta and Shankar, 2022) etc. As TISM offers several advantages over ISM, this paper utilizes TISM for exemplifying the inter-relationships among critical success factors for ESS implementation in grid. Its use is explained in Section 5 along with a step-by-step process.

4.3.4 MICMAC Analysis: The concept of MICMAC analysis is used to identify and group factors into driver power, dependence power, and driving power and then represent it in a graphical representation. The factors's driving power is represented in y-axis, and the factors's dependence power is represented in x-axis. The MICMAC analysis is subdivided into group-A, group-B, group-C, and group-D.

Group A: Autonomous factors – factors associated with this group are hardly supported with another factors, thus, they have weak driving power and weak dependence power.

Group B: Dependent factors: factors associated with this group are affected by other factors and do not impact other factors. These are strongly dependent on another barrier and weekly drives another barrier.

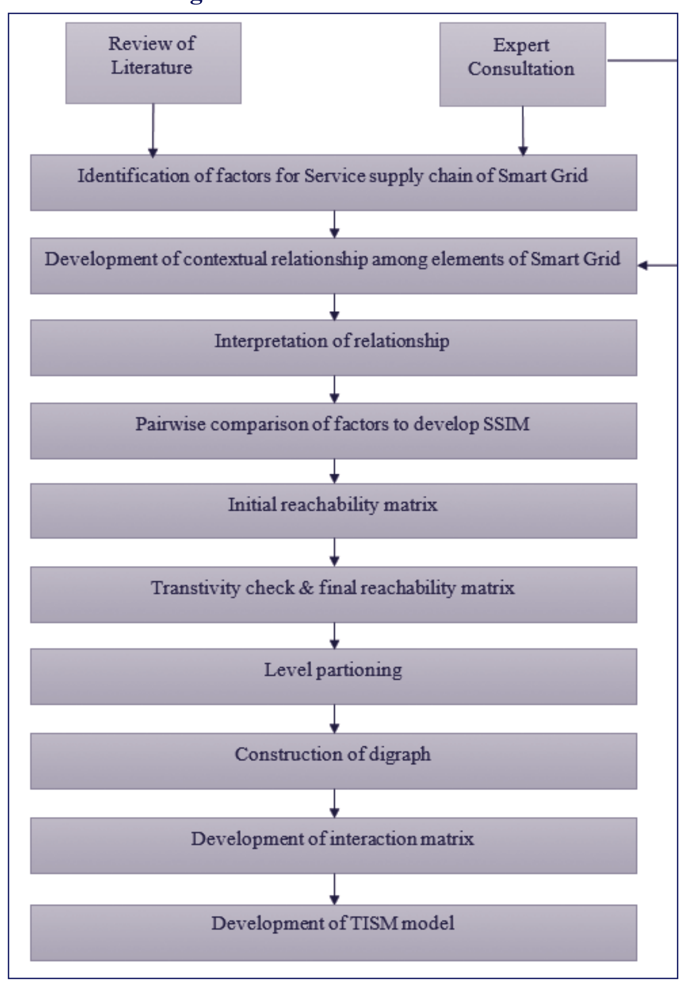
Group C: Linkage factors: Factors that join through a link between drivers and dependence factors. Their dependence and driving power are strong and termed as unstable factors.

Group D: Driving factors: In this group, factors strongly drive others and weakly dependent on other factors. These factors are not affected by some other factors. These factors are very important that need to be considered first.

5. MODELLING INTEGRATED TISM FOR SERVICE SUPPLY CHAIN FOR SMART GRID

The 16 key service factors of the service supply chain of SG are connected in a hierarchical manner using the TISM methodology. The following is an explanation of a seven-step TISM process that is used (Jena et al., 2017). Figure 2, illustrates the suggested research methodology for achieving the defined objective.

Figure 2. Research Framework



Step I: Identification of factors: In this study, we identify 16 important service component responsible for integration in grid by studying the literature review and conducting semi-structured interviews to get input from experts (refer to Table 2) for the service factors for modelling.

Step II: *Determination of contextual relationship:* To achieve the objective of this study, the contextual relationship between different Factors is described as "Factor 1 (F1) will influence or enhance Factor 2 (F2)".

Step III: *Interpretation of relationship:* Expert opinions are gathered to demonstrate if "F-1 will impact or enhance F-2" or not. If this contextual link indicates "yes," it is also shown "how F-1 will impact or increase F-2" (Appendix A).

Step IV: *Interpretive logic-knowledge base for pair-wise comparison:* An "interpretive logic-knowledge base" is developed to express the pair-wise comparison of identified factor. Given that there are two possible directional links—i-j or j-i—there will be a total of 16 (16 -1) = 240 pair-wise comparisons for the 16 identified factors. As a result, the knowledge base for this research will have 240 numbers. Experts' opinions are indicated for each pair-wise comparison by the entry symbols "N" for no and "Y" for yes, and if it is of the "Y" type (Table 3), further interpretation is also provided.

Table 3: Interpretive pair wise comparison

(INTERPRETIVE MATRIX (Expert Opinion																
	F-1	**F-2**	**F-3**	**F-4**	**F-5**	**F-6**	**F-7**	**F-8**	**F-9**	**F-10**	**F-11**	**F-12**	**F-13**	**F-14**	**F-15**	**F-16**
F-1	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	Y
F-2	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y
F-3	N	N	Y	N	Y	Y	Y	N	Y	Y	Y	N	Y	N	N	Y
F-4	N	N	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N
F-5	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N
F-6	N	N	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y
F-7	N	N	N	N	Y	Y	Y	N	Y	Y	Y	N	Y	N	N	N
F-8	N	N	N	N	N	Y	N	Y	Y	N	N	N	Y	Y	Y	N
F-9	N	N	N	N	N	N	N	N	Y	N	Y	Y	Y	N	Y	Y
F-10	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	Y	Y
F-11	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y	Y	N	Y
F-12	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	Y	N
F-13	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N
F-14	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y
F-15	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y
F-16	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y

Step V: Reachability matrix and transitivity test: By assigning 1 for the "Y" and 0 for the "N" in the knowledge base, the initial reachability matrix is constructed from the interpretative logic-knowledge base (Table 4). The transitivity rule is then used to convert the initial reachability matrix into the final reachability matrix. For example, if "F1 relates to F2" and "F2 relates to F5," then "F1 surely relates to F5." Every transitive link is updated in the knowledge base with "Y," and "transitive" is denoted in the corresponding interpretation column. The complete CSF reachability matrix is shown in (Table 5). where 1* indicates that there is a transitive relationship between two enablers.

Table 4. Initial Transitivity Matrix

Initial Reachability Matrix																
	F-1	**F-2**	**F-3**	**F-4**	**F-5**	**F-6**	**F-7**	**F-8**	**F-9**	**F-10**	**F-11**	**F-12**	**F-13**	**F-14**	**F-15**	**F-16**
F-1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1
F-2	1	1	0	1	1	1	1	0	1	1	1	0	1	0	1	1
F-3	0	0	1	0	1	1	1	0	1	1	1	0	1	0	0	1
F-4	0	0	1	1	0	1	1	1	1	1	0	1	1	1	0	0
F-5	0	0	0	0	1	1	1	1	1	1	1	0	0	0	1	0
F-6	0	0	0	0	0	1	0	1	1	1	1	1	1	0	1	1
F-7	0	0	0	0	1	1	1	0	1	1	1	0	1	0	0	0
F-8	0	0	0	0	0	1	0	1	1	0	0	0	1	1	1	0
F-9	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	1
F-10	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1
F-11	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1
F-12	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
F-13	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
F-14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
F-15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
F-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 5. Final Transitivity Matrix

Final Reachability Matrix																
	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-9	F-10	F-11	F-12	F-13	F-14	F-15	F-16
F-1	1	1	1	1	1	1	1	1*	1	1	1	1*	1	1	1*	1
F-2	1	1	1*	1	1	1	1	1*	1	1	1	1*	1	1*	1	1
F-3	0	0	1	0	1	1	1	1*	1	1	1	1*	1	1*	1*	1
F-4	0	0	1	1	1*	1	1	1	1	1	1*	1	1	1	1*	1*
F-5	0	0	0	0	1	1	1	1	1	1	1	1*	1*	1*	1	0
F-6	0	0	0	0	0	1	0	1	1	1	1	1	1	1*	1	1
F-7	0	0	0	0	1	1	1	1*	1	1	1	1*	1	1*	1*	0
F-8	0	0	0	0	0	1	0	1	1	1*	1*	1*	1	1	1	1*
F-9	0	0	0	0	0	0	0	0	1	1*	1	1	1	1*	1	1
F-10	0	0	0	0	0	0	0	0	1*	1	1	1	1	1*	1	1
F-11	0	0	0	0	0	0	0	0	1	1	1	1*	1	1	1*	1
F-12	0	0	0	0	0	0	0	0	0	0	0	1	1	1*	1	1*
F-13	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1*
F-14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
F-15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
F-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Step VI: Level determination by partitioning reachability matrix: To understand the level-wise assignment of factors as mentioned by Ravi and Shankar (2005), the reachability matrix is level partitioned. Table 6 describes level determination by dividing the final reachability matrix for CSFs. These levels are then used to create a digraph and TISM-based model for CSF for ESS implementation in the grid.

Table 6. Partitioning of reachability matrix (iteration 1–10).

Iteration 1:				
Factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
F-1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2	1,2	
F-2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2	1,2	
F-3	3,5,6,7,8,9,10,11,12,13,14,15,16	1,,2,3,4	3	
F-4	3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,4	4	
F-5	5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,7	5,7	
F-6	6,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8	6,8	
F-7	5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,7	5,7	
F-8	6,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8	6,8	
F-9	9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-10	9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-11	9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-12	12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	
F-13	12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	
F-14	14,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	14	
F-15	14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13,15	15	
F-16	16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	16	I

Iteration 2				
Factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
F-1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,	1,2	1,2	
F-2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	1,2	1,2	
F-3	3,5,6,7,8,9,10,11,12,13,14,15	1,,2,3,4	3	
F-4	3,4,5,6,7,8,9,10,11,12,13,14,15	1,2,4	4	
F-5	5,6,7,8,9,10,11,12,13,14,15	1,2,3,4,5,7	5,7	
F-6	6,8,9,10,11,12,13,14,15	1,2,3,4,5,6,7,8	6,8	
F-7	5,6,7,8,9,10,11,12,13,14,15	1,2,3,4,5,7	5,7	
F-8	6,8,9,10,11,12,13,14,15	1,2,3,4,5,6,7,8	6,8	
F-9	9,10,11,12,13,14,15	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-10	9,10,11,12,13,14,15	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-11	9,10,11,12,13,14,15	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-12	12,13,14,15	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	
F-13	12,13,14,15	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	
F-14	14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	14	II
F-15	14,15	1,2,3,4,5,6,7,8,9,10,11,12,13,15	15	

Iteration 3				
Factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
F-1	1,2,3,4,5,6,7,8,9,10,11,12,13,15,	1,2	1,2	
F-2	1,2,3,4,5,6,7,8,9,10,11,12,13,15	1,2	1,2	
F-3	3,5,6,7,8,9,10,11,12,13,15	1,,2,3,4	3	
F-4	3,4,5,6,7,8,9,10,11,12,13,15	1,2,4	4	
F-5	5,6,7,8,9,10,11,12,13,15	1,2,3,4,5,7	5,7	
F-6	6,8,9,10,11,12,13,15	1,2,3,4,5,6,7,8	6,8	
F-7	5,6,7,8,9,10,11,12,13,15	1,2,3,4,5,7	5,7	
F-8	6,8,9,10,11,12,13,15	1,2,3,4,5,6,7,8	6,8	
F-9	9,10,11,12,13,15	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-10	9,10,11,12,13,15	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-11	9,10,11,12,13,15	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-12	12,13,15	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	
F-13	12,13,15	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	
F-15	15	1,2,3,4,5,6,7,8,9,10,11,12,13,15	15	III

Iteration 4				
Factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
F-1	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2	1,2	
F-2	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2	1,2	
F-3	3,5,6,7,8,9,10,11,12,13	1,,2,3,4	3	
F-4	3,4,5,6,7,8,9,10,11,12,13	1,2,4	4	
F-5	5,6,7,8,9,10,11,12,13	1,2,3,4,5,7	5,7	
F-6	6,8,9,10,11,12,13	1,2,3,4,5,6,7,8	6,8	
F-7	5,6,7,8,9,10,11,12,13	1,2,3,4,5,7	5,7	
F-8	6,8,9,10,11,12,13	1,2,3,4,5,6,7,8	6,8	
F-9	9,10,11,12,13	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-10	9,10,11,12,13	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-11	9,10,11,12,13	1,2,3,4,5,6,7,8,9,10,11	9,10,11	
F-12	12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	IV
F-13	12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	IV

Iteration 5				
Factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
F-1	1,2,3,4,5,6,7,8,9,10,11	1,2	1,2	
F-2	1,2,3,4,5,6,7,8,9,10,11	1,2	1,2	
F-3	3,5,6,7,8,9,10,11	2,3,4,,1	3	
F-4	3,4,5,6,7,8,9,10,11	1,2,4	4	
F-5	5,6,7,8,9,10,11	1,2,3,4,5,7	5,7	
F-6	6,8,9,10,11	1,2,3,4,5,6,7,8	6,8	
F-7	5,6,7,8,9,10,11	1,2,3,4,5,7	5,7	
F-8	6,8,9,10,11	1,2,3,4,5,6,7,8	6,8	
F-9	9,10,11	1,2,3,4,5,6,7,8,9,10,11	9,10,11	V
F-10	9,10,11	1,2,3,4,5,6,7,8,9,10,11	9,10,11	V
F-11	9,10,11	1,2,3,4,5,6,7,8,9,10,11	9,10,11	V

Iteration 6				
Factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
F-1	1,2,3,4,5,6,7,8	1,2	1,2	
F-2	1,2,3,4,5,6,7,8	1,2	1,2	
F-3	3,5,6,7,8,	1,,2,3,4	3	
F-4	3,4,5,6,7,8	1,2,4	4	
F-5	5,6,7,8	1,2,3,4,5,7	5,7	
F-6	6,8	1,2,3,4,5,6,7,8	6,8	VI
F-7	5,6,7,8	1,2,3,4,5,7	5,7	
F-8	6,8,	1,2,3,4,5,6,7,8	6,8	VI

Iteration 7				
Factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
F-1	1,2,3,4,5,7	1,2	1,2	
F-2	1,2,3,4,5,7	1,2	1,2	
F-3	3,5,7	1,,2,3,4	3	
F-4	3,4,5,7	1,2,4	4	
F-5	5,7	1,2,3,4,5,7	5,7	VII
F-7	5,7	1,2,3,4,5,7	5,7	VII

Iteration 8				
Factors	Reachability set	Antecedent set	Intersection set	Level
F-1	1,2,3,4	1,2	1,2	
F-2	1,2,3,4	1,2	1,2	
F-3	3	1,,2,3,4	3	VIII
F-4	3,4	1,2,4	4	

Iteration 9				
Factors	Reachability set	Antecedent set	Intersection set	Level
F-1	1,2,4	1,2	1,2	
F-2	1,2,4	1,2	1,2	
F-4	4	1,2,4	4	IX

Iteration 10				
Factors	Reachability set	Antecedent set	Intersection set	Level
F-1	1,2	1,2	1,2	X
F-2	1,2	1,2	1,2	X

All iterations associated with level partitioning (1to 10)				
Factors	Reachability set	Antecedent set	Intersection set	Level
F-1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2	1,2	X
F-2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2	1,2	X
F-3	3,5,6,7,8,9,10,11,12,13,14,15,16	1,,2,3,4	3	VIII
F-4	3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,2,4	4	IX
F-5	5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,7	5,7	VII
F-6	6,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8	6,8	VI
F-7	5,6,7,8,9,10,11,12,13,14,15,16	1,2,3,4,5,7	5,7	VII
F-8	6,8,9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8	6,8	VI
F-9	9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11	9,10,11	V
F-10	9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11	9,10,11	V
F-11	9,10,11,12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11	9,10,11	V
F-12	12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	IV
F-13	12,13,14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13	12,13	IV
F-14	14,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	14	II
F-15	14,15,16	1,2,3,4,5,6,7,8,9,10,11,12,13,15	15	III
F-16	16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	16	I

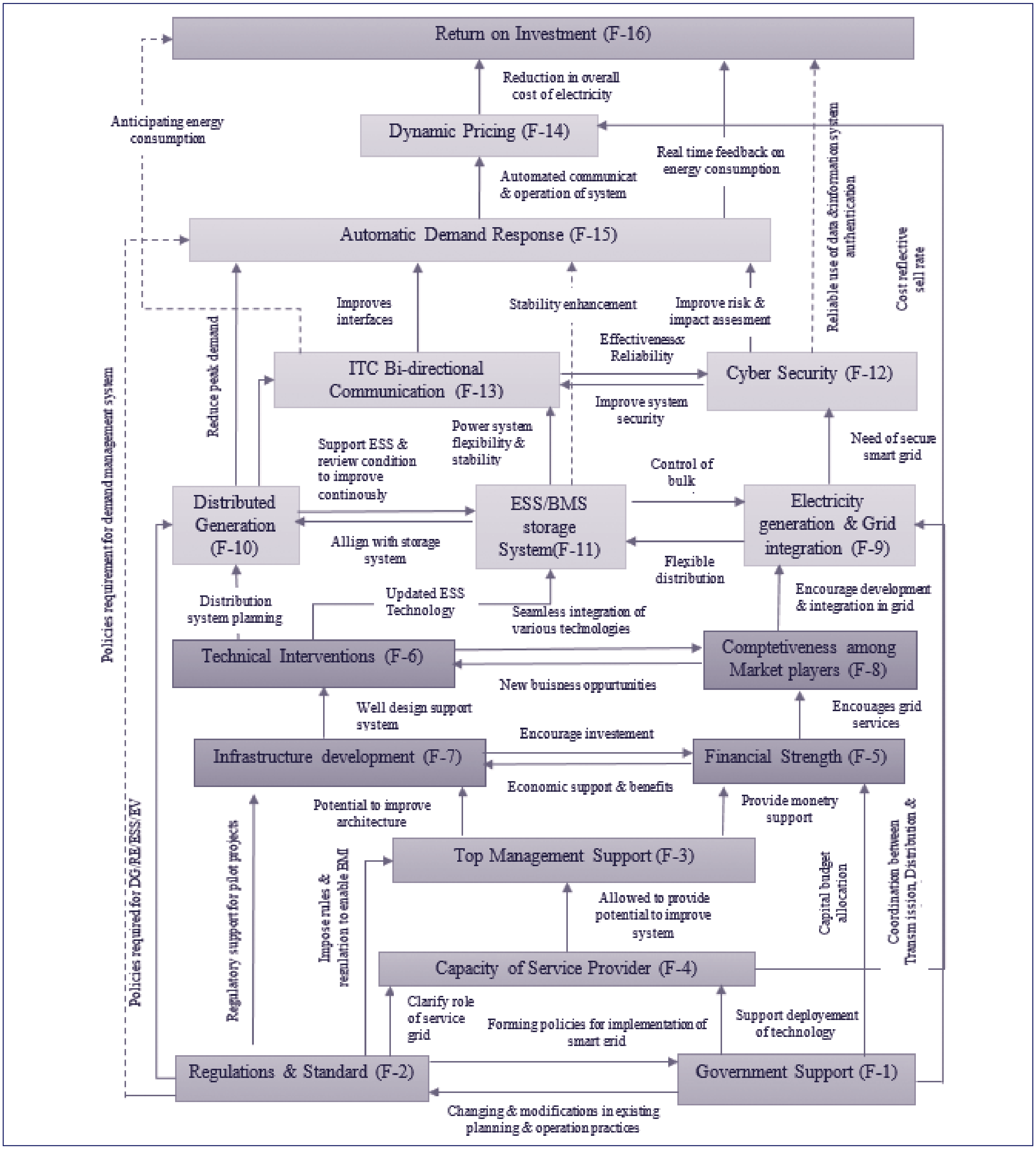
Step VII: Develop digraph: By placing each element at its appropriate level and displaying directed linkages in accordance with the relationship shown in the final reachability matrix, a directed graph for all factors is created.

Step VIII: Interpretive matrix: The final digraph is first converted into a binary interaction matrix by marking all interactions in the appropriate cells with a "1". After that, a binary interaction matrix containing "1" cells is converted into an interpretative matrix by taking into account the corresponding interpretation from the interpretive logic-knowledge base. In

Appendix A, an interpretation matrix for service supply chain for smart grid factors is shown.

Step IX: Total interpretive structural model: The interpretative matrix and digraph are used to create a TISM-based model for CSFs. A digraph's nodes show how several factors are interpreted. On the other hand, the relevant link's side displays the information that was obtained using the interpretative matrix. It offers a comprehensive interpretation of the structural model in terms of understanding both nodes and links in this way. Finally, Figure. 2 illustrates a integrated TISM for service supply chain for smart grid. Here, solid lines denote direct relationships, whereas dotted lines indicate important transitive links.

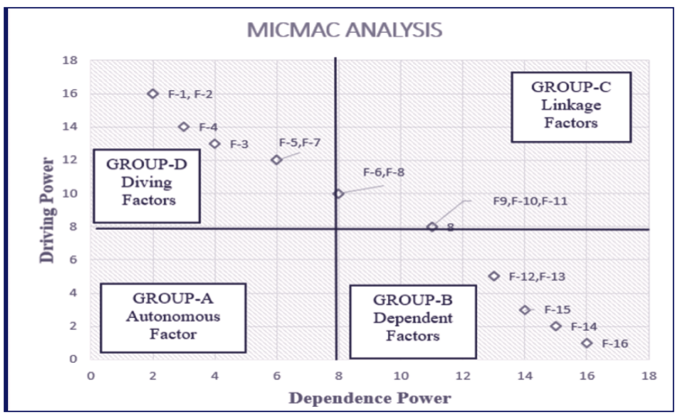
Figure 2. TISM model for service supply of smart grid



5.1 Classification of MICMAC Analysis: Using the concept of MICMAC analysis, CSFs are identified, categorised into driving & dependence power, and then it is shown graphically (Figure 3). The y-axis displays the factor's driving power, while the x-axis displays the factor's dependence power. There are four groups in the MICMAC analysis: group A, group B, group C, and group D.

- **Group-A i.e.,** Autonomous Factor Usually, this group consists of those Factors with weak drivers and weak dependents. Here no factors found to be autonomous factors
- **Group-B i.e.** Dependent Factors, as they are strongly dependent upon certain factors and drive others weakly. Group B involves five factors F-12,F-13,F-14,F-15,F-16
- **Group C** contains linkage Factor in which any effect of these factors influences other Factor. Here factors is identified i.e., F6,F-8,F-9,F-10,F-11
- **Group D** factors strongly drive others and weakly dependent on other factors in our case group D have following F1, F-2, F3, F4, F5, F-7

Figure 3. Classification of MICMAC Analysis



6. RESULTS & DISCUSSION

This study develop a hierarchical model for smart grid supply chain variables to understand their driving and dependence power in the electricity sector. Further, emperical analysis is used to analyze relationship among different variable of service supply chain of smart grid to identify the most significant factor among all service components. TISM classifies the factors of service supply chain of smart grid into ten different levels and MICMAC method is used for categorizing the identified factors into four groups. The key findings associated with this phase of the research are summarized below: This framework will categorize the following factors into 4 categories i.e. strategic factor, tactical factors, operational factors and performance factor, where strategic based factors termed to be drivers' factors and performance-based factor are termed to be a dependent factors. Further, it develops a framework in the hierarchical model to investigate interrelationship among the identified factors. The results of the TISM are in ten levels: At the first level; Return on Investement. At second level: Dynamic Pricing. At Third level: Automatic demand response. At fourth level: ICT bidirectional communication and cybersecurity. At the fifth level: Distributed generation, Energy storage system and generation system& grid integration; At the sixth level: Technical interventions and comptetion among market At the seventh level: Infrastructure development and Financial strength At the eight-level: Top management support; At ninth level: Capacity of service provider; At tenth level: Regulations and standards and Government support. This research provides a complete thoughtful on the directional interrelationships between each factors and delivers the best possible solution for the active operation of the smart grid and its performance. Also, finds crucial factor which confine the active process of the smart grid while integrating through energy storage system This model will support policymakers in building knowledgeable decisions in the smart grid system to improve performance of power grid through services offered in its supply chain. The results specify that Energy storage act as a central role which will enhance the operation of the smart grid and has ability to provide application-specific energy services across different components throughout the smart grid. There is a need for government support to ensure adequate strategic planning requirements and appropriate infrastructure investments to implement re-planning and technical interventions to create new service components in the supply chain of smart grid which will increase its performance with maximum return on investement. Although BMS is a operational factor (comes under Linkage factors) it holds high importance on Smart Grid service supply chain. ESS/BMS will have high driving factors among all operational factors of TISM to achieve maximum profitability in smart grid.

6.1. Role of energy storage in service supply chain of the smart grid: Energy storage can provide multiple services for generation, transmission, and distribution ESS is complementary in meeting the goals of an efficient smart grid. The proposed benefits of smart grids to utility companies and the electricity system as a whole include improved reliability with less costly interruptions, deferred capital spending on costly transmission and generation assets, and increased efficiency of power delivery due to lower distribution losses. Energy storage meets these benefits by negating the need for extra peaking generation through load leveling, deferring the transmission and distribution upgrades needed to meet load growth with a smaller sized energy storage investment, reducing transmission congestion fees in deregulated markets by adding energy storage to distribution substations, and providing the load following capabilities that will help improve the intermittency of renewable energy sources. Electric energy storage as a key enabler and enhancer of dispatchability of renewables; provides options to offset the mismatch between demand and supply and to operate the distribution system in a more efficient, economic, and environmentally sound manner. Lastly, with smart grid technologies and energy storage in place, benefits to residential consumers will include cost savings from peak load management, energy efficiency, and increasingly affordable distributed renewable energy systems. ESSs are utilised in the electric power sector for a variety of purposes, including RE exploitation, commodity arbitrage, transmission assistance, distribution deferral, power quality, DG support, and off-grid electricity delivery. There are several advantages to ESS, one of which is the possibility of striking a balance between the production and consumption of power. ESS is used to improve power quality.

7. MANAGERIAL IMPLICATIONS

Our results show the need for government initiatives to ensure adequate strategic planning requirements and appropriate infrastructure investments to implement re-planning in the transmission sector to expand battery integration in the grid. As each stakeholder plays a different role in the smart grid, this study will help the managers to sense the significance of each barrier to understanding the driver and dependences relationship between the factors by considering the views of multiple experts. Consequently, all investors such as policymakers, manufacturers, EPC servicers, financial providers, customers, central and state services must promote their long-term efforts to maintain continuous modifications in the present transmission system while integration with a renewable energy source. Effective guidelines and strategies can be outlined to run equal figures to knowledgeable private players when presenting and implementing power transmission projects. This study offers valued perceptions concerning their importance and interdependencies between these factors. Managers should immediately deal with driver barrier as they are likely to impact the factors present in the upper level of the TISM model because of strong driving power. Therefore, efforts should have directed toward policy interventions, increasing the funds for technical infrastructure and current technologies, good collaboration between private players, adequate investment in power systems, and providing skill development training to personal on advanced technologies. Considering the power system, there is a significant requirement to integrate renewables and storage systems for high-tech inventions outside the transmission grid. Hence, by understanding these factors, top management people of power sector area can be helped by knowing interrelationships among different factors and suggested solutions to justify the effective implementation of advanced grid technology.

8. CONCLUSION

This study develops a hierarchical model for smart grid supply chain variables to understand their driving and dependence power in the electricity sector. TISM is used to analyze relationship among different variable of service supply chain of smart grid to identify the most significant operational factor among all service components. It classifies the factors of service supply chain of smart grid into ten different levels. Further, MICMAC analysis is used for categorizing the identified factors into four groups. This research gives possible ways to run the future smart grid supply chain in an efficient secure and reliable manner. This research explains how a unified energy storage system is an important part in building a smart grid environment and discussed the role of ESS in service management layer of proposed approach. Energy storage technologies provide significant opportunities to further enhance the efficiency and operation of the grid. Its ability to provide application-specific energy services across different components of the grid make it uniquely suited to respond quickly and effectively to signals throughout the smart grid. Therefore, energy storage as a distinct asset class in a central role will increase the value of storage investments while enhancing the operation of the smart grid. To further attain this goal, power grid requires government support, regulations standards, capability of service provider, financial strength and infrastructural development. This study gives an insight into the current energy scenarios of India, potential, initiatives, and policy regulation, including the potentialities of renewable energy sources to achieve sustainability in energy in order to meet the sustainable development goals.

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