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Critical Solution to Power Grid Problems Using Smart Grid – A Case Study on Karnataka Power Transmission Control Limited (KPTCL)

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Abstract

Karnataka Power Transmission Corporation Limited (KPTCL) is a power distribution and transportation company in Karnataka state established in the year of 1999 under the company act 1956. Now it is one of the big government sector company owned by government of Karnataka with 1000 cores of share capital. Karnataka Electric Board (KEB) is the parent body of KPTCL, until 2002 KEB did all the functions such as distribution and transmission of electric power throughout the state. After that it was divided in to distribution and Transmission Company called KPTCL and power generating company known as Karnataka Power Corporation Limited (KPCL). The ultimate goal of KPTCL is to provide uninterrupted power supply to all customers in state of Karnataka with minimum distribution and transmission cost and lowest unit price. KPTCL purchases power from KPCL for fixed rate under the Karnataka regulation act. KPCL contains several power generation projects which include different types such as hydraulic power, thermal power, wind power, etc. KPTCL also purchases power from power stations such as National Thermal Power Corporation (NTPC) and Atomic power stations like Kalpakkam and Kaiga which is owned by central government. Power generation is not a big deal for any state government but real challenge is to transmission of uninterrupted power and distribution of power to different parts of the state using power grid. So there should be proper data analysis in the entire grid and all transmission station throughout the state in order to identify the loop holes, actual capacity, requirement, request from consumers, and also to identify any damages. The ultimate solution for all this is introduction of smart grid concept in power grid. In this paper I reviewed about operational and technical structure of the KPTCL and factors to be considered while performing data analytics in power grid and adoption of smart grid concept over traditional grid using SCADA technology to perform data analytics and finally listed out some improvements in overall functioning of KPTCL after implementation of smart grid.

Keywords: smart grid, KPTCL, transmission, distribution, smart meter, transmitter, SCADA, PMU, BDA.

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1. Introduction

KPTCL is power transmission and Distribution Company owned by government of Karnataka which is the only company in Karnataka state which is monopoly in the sector. Like other company KPTCL is also having its own management structure which is hierarchical in nature. KPTCL has different sub companies called Electricity Supply Companies (ESCOM'S) based on geographical region such as MESCOM, BESCOM, CHESCOM, SESCOM etc. all these sub companies has same management team with similar structure. It purchases power from Karnataka Power Corporation Limited (KPCL) or other private companies like Reliance, Jindal or also it purchase power from consumers. It should have proper distribution network structure to transmit the power to various parts of the state. Distribution and transmission network contains different components like power stations, sub stations, power grids, transformers, power meters, station meters etc. the production, transmission and distribution are separate units because of that there is a huge gap between these units. Here transmission and distribution units facing lot of problems, result of that there is a huge power loss, black holes, load problems etc [21]. To overcome from such situation there should be automation in power sector that can be implemented using Supervisory Control and Data Acquisition (SCADA) [1].

The electrical power transmitted from different generating station to different receiving substation through transmission line. The major operating concern of KPTCL was to maintaining security, quality of power, reliability, and giving stable power and to ensure economically good operation. It can't fulfill this using only the man power, so it requires fully automated and computerized solution that is SCADA. Karnataka government and KPTCL implemented this technology so that from last 12 decades there are no single black holes in state of Karnataka [1]. Also KPTCL distributes authentic and efficient power supply to its entire consumer. The SCADA definition recommended by IEEE is "A collection of equipment that will provide an operator at a remote location with sufficient information to determine the status of particular equipment or process and cause action to takes place regarding that equipment or process without being physically present [18]. One can also analyze the data using SCADA while it stores the data, list station or in corporate office one can easily analyze those data and he can sort out the problem. So the full-fledged SCADA is a technology for monitoring entire system, controlling, fault detection and prevention and to make distribution and transmission activities easier and faster. Big data analytics (BDA) is one of the powerful technique used in large consumer based industry like power industry helps to take decision in different dimensions in terms of business aspect as well as consumer side [2]. Especially in power sector there is an limitless opportunities for BDA to provide feedback loop from one substation to another substation or one office to another office which enhances the planning as well as accurate realization of some critical problems which leads to take good decisions and leads to conduct some informed operations.

2. A Big Data in Power Sector

The 3 V factors of big data such as volume, velocity and variety will be generated by various components in power distribution and transmission network.
Volume: The volume of the data usually we measured in terms of Giga Byte (GB) or Tera Byte (TB) or Peta Byte (PB). The data may be generated from the customer side like customer's feedback or customer's complaints or customer's queries, customer's request etc. also data will be generated from social media, electronic media, print media etc. Advanced meter reading (AMI) will collect data by meter reading from millions of customers all across the Karnataka. Smart meters and Phaser measurement units (PMU) contains sensors that will generate data related to different issue in every second or every time intervals[5]. Millions of such sensors are connected across the power grid and imagine the amount of data that sensors are possible to generate. Also the possibility of data generation if there is any demand from any part of the power grid and also possible response again data will be sent back to requested grid. Data from the prosumers again they are producers as well as consumers. Also data generated from assent monitoring and controlling system, Weather related data and financial and marketing related data [5].

Velocity: Velocity of the data is nothing but how fast the data will be generated and transmitted across the power network or one grid to another grid. There are 3 types of data with respect to velocity called batch data, online data and stream data. In batch data where data will be generated and transmitted in batch wise with every time interval like every one second or every one minute or every one hour. Online data is data pertaining to web application or web site or social media. Stream data will be obtained continuously by different sensors that are related to operational side of the power grid. Data generation and transformation will happen during planning process, capacity management process, cyber security assessment process, event analysis, market and trading process and from customer side. Majority of power system sensors are event triggered, these sensors will produce data when particular event has been happened in the system. In SCADA network contains PMU has different sensors that will continuously generates and transmits the data signals over the network.

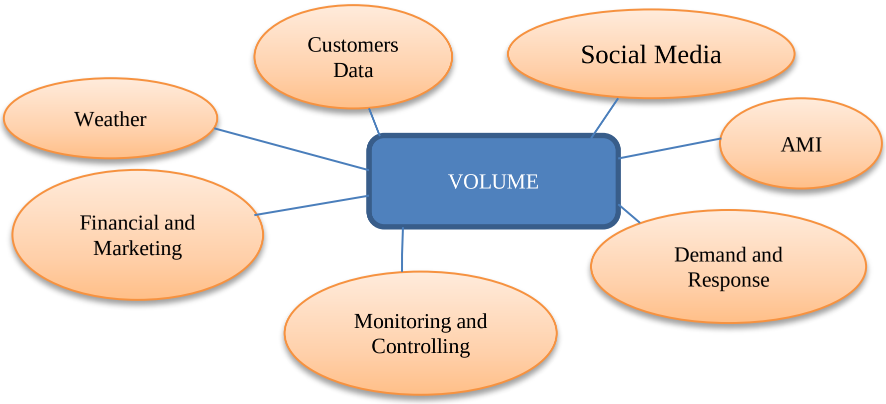

Fig 1. The volume of the data generated by multiple components in power sector

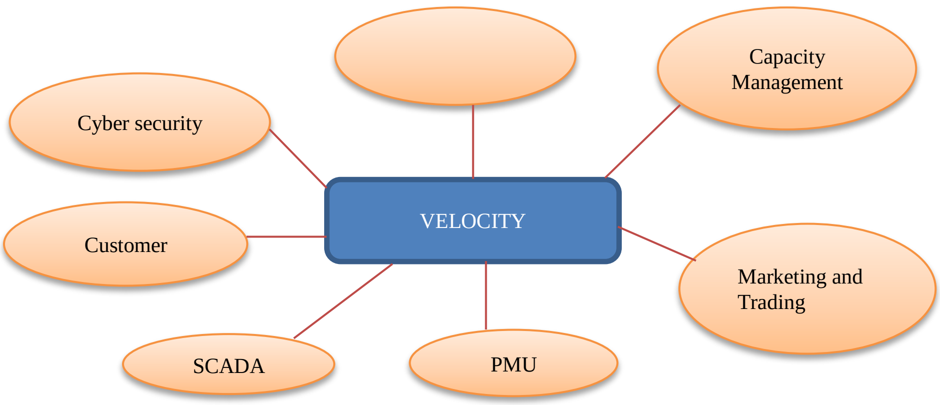

Fig 2. Different components that causes velocity of data generation and transmission

Variety: In modern smart grid technology variety of data comes from different sources. Different sources are smart meters, substation meters, voltmeters, fault detectors etc. smart meter reads the total amount of units consumed by the consumer. Substation meter also reads the active and reactive power reading in every time interval. PMU sensors will read voltage magnitude and phase angle reading in every time interval. Like this various meters and sensors will produce different varieties of data depends on functionality as shown in Fig.3 [25].

3. A Big Data Analytics in Power Grid

Data analytics is possible in power grid in different aspects such as

a. Outage management: there was huge power loss in old system, but after implementation of smart grid, through data analysis there it was possible to manage the power outage. Power outage is drastically reduced after implementation of smart grid using SCADA and PMU in power grid [12].
b. Consumer behavior: It was possible to predict the behavior of power consumer, in which particular season of the year or which particular time of the day consumer consumes more power. Also can able to predict which part of the state consumer consumes more power, so that company can able to manage such situation, so consumer gets stable power supply from the company.
c. Demand/ Capacity: In some situation few substation demands for more power that is automatically intimated to the grid also it will analyze whether the transmission line have enough capacity to accommodate more power that it demands for. If it possible to supply more power than only they supply more power based on the demand requirement without any damage. All these technical aspects of the operation of power sector are easily performed with the help of data analytics in smart grid technology [14].
d. Workforce management: Due to availability of data in all the offices of KPTCL, it was easy job for officers to allocate work for employees. After analyzing the data officers can able to know the place where some defects occurred, so it can be managed by allocating some work force to that place and can easily handle.
e. Energy Theft: Energy theft is the biggest problem in power sector that can be handled after implementation of smart grid. It can able to find which particular transformer or in which substation the energy theft is happening, so company can handle such problems [12].
f. Crisis management: Some internal factors and external factors or environmental factors will affect the operation of the system. After implementation of smart grid all these crisis can be managed because it can able to send corresponding warning messages very quickly before or after any such crisis are occurred [5].
g. Forecasting: Smart grid can also performs data analytics for future needs such as power demands, consumer requirements, line extensions, need of transformers, and need of any other components, whether forecast etc. So it is very helpful for company to fulfil the requirement for future [23].

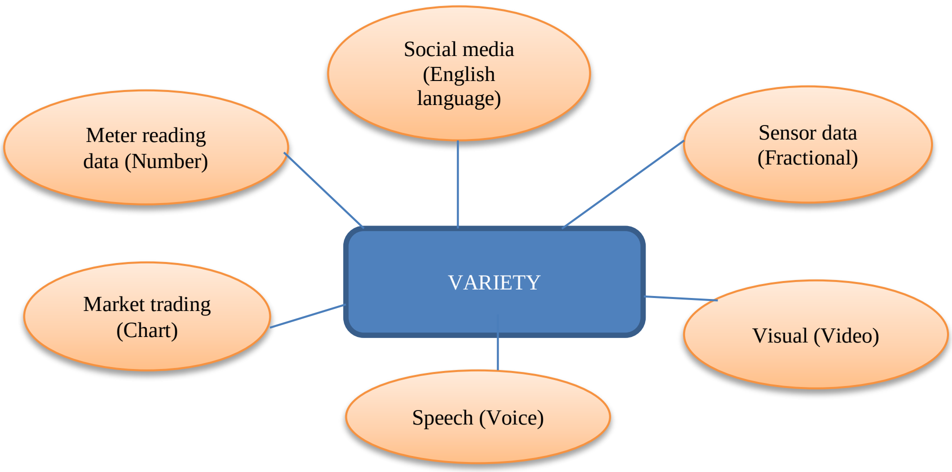

Fig 3. Illustrates the varieties of data generated in power sector

4. A Typical View of Smart Grid

The smart grid in power sector contains different components as shown in figure 4. In this different components are interconnected to each other that communicate each other by passing data from one component to another. In order to communicate it uses mainly SCADA technology or PMU technology using satellite based communication [17]. Also it has different types of sensors that generates and sends the data to other components of the grid. There is a centralized control in the network as shown in figure 4, it controls and manages all the aspects of the grid by sitting at on place. As all the components interconnected, so it is also possible to gather and analyze of data at any components of the grid, so it helps the power sector to become more stabilized and reliable unit [15][35].

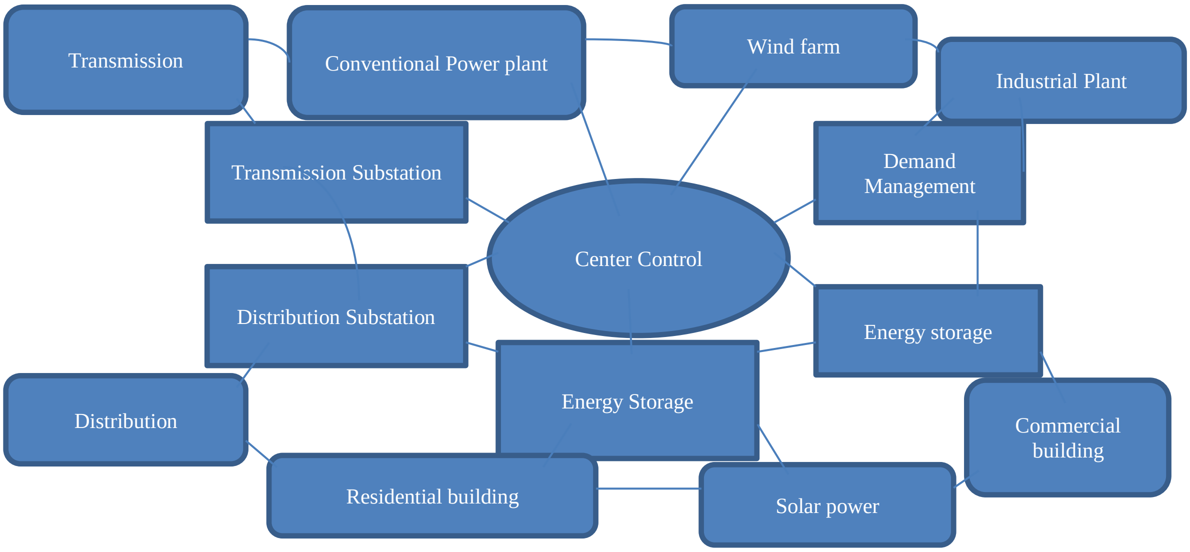

Fig 4. The typical view of the conventional power smart grid

5. SCADA (Supervisory Control and Data Acquisition)

SCADA is the most sophisticated technology used by KPTCL to automate the power system in distribution and transmission network to supply quality power. It will constantly monitor the power system by sending data across the network and MCC (Master Control Centre). Also used to control and operate substations electrical components such as breakers, GOS, Relays etc. Energy management system of SCADA monitors energy consumption from energy generating station, supply of energy through transmission and distribution of power through various substation and load control process [11]. Thus SCADA is a powerful technology used in power sector that will automate the entire process in power sector with less human intervention. It includes the functionality such as trending, alarm handling, achieving, report generation, switching, regulating, report generation, controlling, protection etc [28]. SCADA collects data from all feeders ranging from 11 KV to 400 KV and sends data to Load Dispatch Center (LDC), thus facilitates to record data, event list, disturbances, trip values etc. So it helps operators to identify, analyze and to make necessary actions during critical situations.

These data are very much required to monitor, control, fault detection, prevention from disaster and to make stable power supply activities across the state with easier and faster [32]. The SCADA technology can be categorized in to 3 main areas –

- Remote Terminal Units (RTU): It provides analog and digital sensors that have placed across the power network in remote site. Typically it converts electrical signal in to the digital values from various physical equipment that measures voltage, current, pressure, flow, temperature etc. RTU can also control the equipment's or sensors to converting and sending signals through communication network.
- Communication network: It provides a path way to communicate RTU and Network and Management System (NMS) or master station. Communication network may be wired or wireless communication. In wired communication it uses fiber optic or telephone cables and in wireless communication it uses radio wave or microwave or satellite communication systems.
- Network Management System (NMS): It contains master stations or sub masters to obtain data from various RTU's through communication network. It provides a user interface to present the data as well as to process the data. There by it manages the remote site where the data was obtained [11].

6. The Hierarchy of SCADA Components

As mentioned in Fig 5 these are the main 5 components of SCADA system. Here different equipment's or sensors that are placed at remote locations of power grid component. These sensors will be placed in production location, transmission location or distribution or consumer location. Remote Terminal Units (RTU's) are also placed at different locations that receives digital or analog signals from these equipment's and sends the data to master station through the proper communication system. Communication system used by KPTCL is VSAT communication system using satellite. Master stations or different sub master stations having proper software's to receives the data and performs data processing task and displays proper information and automate the task. It contains different data processing systems that processes the different kinds of data based on requirement [39].

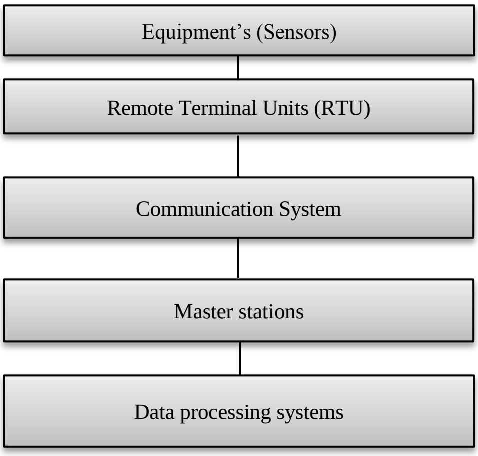

Fig 5. The hierarchy of various components in SCADA technology

7. SCADA System Architecture At KPTCL

The SCADA network at KPTCL contains 16 master stations or control centres which includes Main Control Centres (MCC), Disaster Recovery and Management Control centres (DRMCC), Area Load Dispatch Centres (ALDC) for all the ESCOMs. Where transmission RTU is communicate with MCC1, distribution RTU is communicate with MCC2, disaster RTU is communicate with DRMCC and load dispatch RTU is communicate with ALDC etc. here overall system is configured with 72 servers and 115 workstations. It uses VSAT communication system having its own VSAT hub and leased lines for inter centre communication [30].

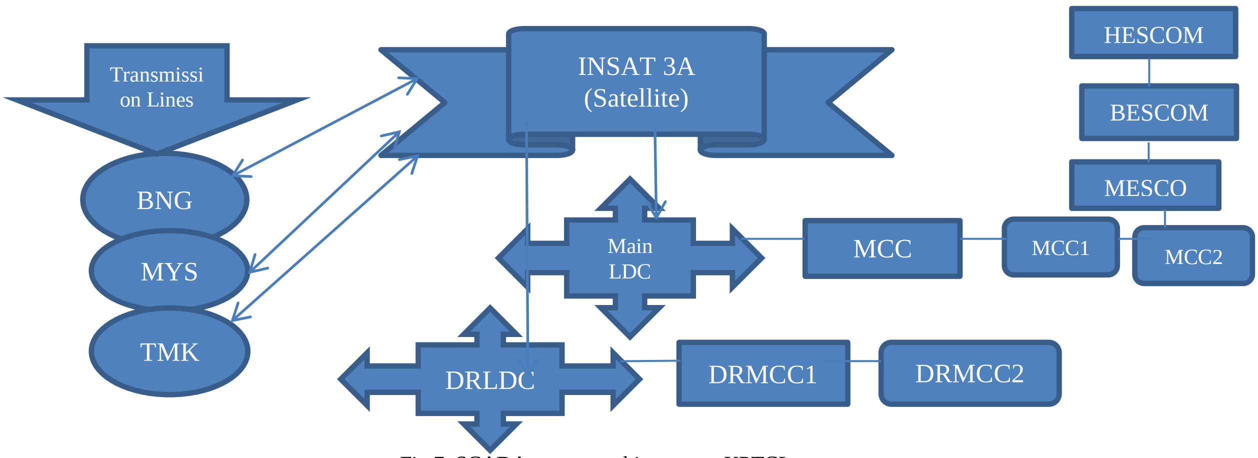

Fig 7. SCADA system architecture at KPTCL

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KPTCL covers all the substations ranging from 33KV TO 400KV. At the first phase it was implemented in Bijapur city. SCADA equipment's, connection and operation are implemented in all 110/11KV substations. Replacement of old equipment with new SCADA equipment is not easy and also it is not economical it involves more cost. So KPTCL instead of replacing old equipment it step towards automating existing equipment's by installing Remote Terminal Units (RTU) it sends information to Master Control Center (MCC) [6].

As mentioned in Fig. 7 the system architecture of SCADA at KPTCL, it mainly works based on three components such as Remote Terminal Unit (RTU) installed on Remotes sites like Bangalore or Mysore or Tumkur as mentioned in Fig. 7 which sends the data to transmission media. The transmission media used here is V-SAT technology that works based on satellite. This satellite retransmits the data to Master Control Stations (MCC) through Load Dispatch Control (LDC) as shown in fig. 7. There are plenty of MCC's will be placed such as main MCC which processes actual data required for different ESCOMS and also it contains DRMCC which processes data for disaster and recovery, like wise it has several MCC's for processing data based on different requirements.

8. Very Small Aperture Terminal (VSAT)

VSAT is main communication media for KPTCL and Electricity Supply Company (ESCOMs) in SCADA network. And also it provides voice communication to all KPTCL, all main stations of ESCOM's such as BESCOM, MESCOM, GESCOM, HESCOM and major power generation stations with load dispatch center (LDC). VSAT is mainly designed with the purpose of data transmission and distribution over large geographical area [8]. With the help of VSAT, KPTCL monitors, regulates, transmits, processes and delivers the electricity data of above 14.5 million customers and across the Karnataka it covers area around 1,92,000 sq.km. VSAT communication system mainly contains different components such as antenna, Indoor Unit (IDU), Outdoor Unit (ODU), SCADA phone, 8 port switches, Voice over Interne Protocol (VoIP) [19].

9. VSAT Implementation

The implementation of VSAT is mainly works based on modeling and simulation of radio frequency (RF) communication link between satellite transponder and receiving antenna. A satellite transponder contains series of units that generated radio frequency (RF) communication between receiver and transmitter antenna in a communication satellite [9]. Mainly C band communication satellite is used here and each transponder of the satellite is amplified with travelling wave tube amplifier (TWTA) or solid state power amplifier (SSPA). These transponders will transmits the data at the range of 1000Kbps to 256Mbps [10]. To achieve this high data transmission it uses one more unit called repeater.

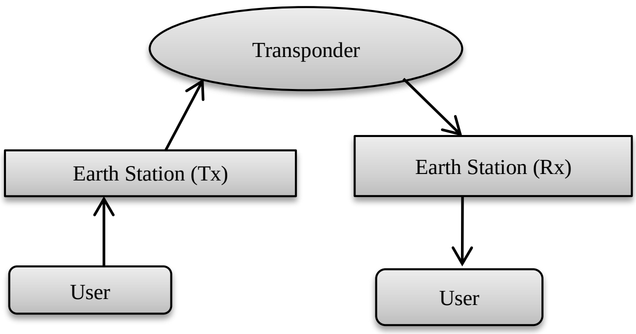

Fig. 8. Basic VSAT Communication System

VSAT communication system has several earth station units that is located in different geographical area and these earth stations are linked with transponder in satellite. User is connected with any one of the earth station through terrestrial network as shown in figure 8. The terrestrial network mainly contains leased lines or telephone lines or OFC cable. The user produces data in the form of base band signal that is processed with terrestrial network and transmitted to satellite through VSAT earth station. The satellite transponder consist large number of repeaters in space that receives radio frequency (RF) carrier signals in uplink frequency spectrum from all the VSAT earth station in the network. It amplifies this carrier signal and retransmits the signal back to other VSAT earth station in its downlink frequency spectrum [19]. The radio frequency signals at receiving earth station are processed and convert to baseband signal that transmitted back to end user through terrestrial network.

10. VSAT Configuration

The frequency and band width values of both satellite and earth station antenna of VSAT communication system are given in the table 1. These are the standards that were set by KPTCL to send and receive data across the network through VSAT communication system [32].

Table 1. The configuration values in different aspects of VSAT communication system

Description	Value
Earth station transmitter antenna gain	52.48db
Satellite transmitter antenna gain	31db
Earth station receiver antenna gain	36.85db
Satellite receiver antenna gain	38.2db
Transponder band width	36 MHz
Up-link frequency band	6.875 – 6.9465 GHz
Down-link frequency band	4.650 – 4.7215 GHz
Up-link loss and down-link loss	22 -217 db

11. Conclusion

Data and data analysis is integral part of any sustained company in order to give the best service to customers their bye to improve its business. How to collect data and how to perform data analysis is the big challenge for the company. To achieve this KPTCL was implemented the SCADA technology and that was the perfect choice to them to overcome all problems. Before implementing SCADA there was huge power loss and black out problem all over the state. KPTCL could not able to find out where was the real problem. But after implementation of SCADA it can easily sorted all the problems automatically. There was no single black out in a day after SCADA implementation. Also KPTCL gain big success in all the aspects like business, operational and technical aspect. So the technology reached to greater extent so that it’s our determination to use such technology to gain success in any sector. KPTCL successfully proved that by performing data analysis using SCADA technology.

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References

[1] Bala, S. K. (2013). Study of Smart Grid Technology and Its Development in Indian Scenario (Doctoral dissertation).
[2] Sinha, A., Neogi, S., Lahiri, R. N., Chowdhury, S., Chowdhury, S. P., & Chakraborty, N. (2011, July). Smart grid initiative for power distribution utility in India. In 2011 IEEE Power and Energy Society General Meeting (pp. 1-8). IEEE.
[3] Bala, S. K., Babu, B. C., & Bala, S. (2012, March). A review on development of smart grid technology in India and its future perspectives. In 2012 Students Conference on Engineering and Systems (pp. 1-6). IEEE.
[4] Koluragi, V. V. (2014). A Case Study: SCADA Implementation in KPTCL. *International Journal of Engineering Research and Technology*,3(10),1-10.
[5] Akhavan-Hejazi, H., & Mohsenian-Rad, H. (2018). Power systems big data analytics: An assessment of paradigm shift barriers and prospects. *Energy Reports*, 4(1), 91-100.
[6] Girish, V., & Ananthapadmanabha, T. (2017). Novel Clustering-based Hidden Markov Model (CHMM) optimization approach for optimal PMU placement. *Russian Electrical Engineering*, 88(3), 178-184.
[7] Dahmash, F. N. (2015). Size effect on company profitability: Evidence from Jordan. *International Journal of Business and Management*, 10(2), 58-59.
[8] Surekha, T. P., Ananthapadmanabha, T., & Puttamadappa, C. Performance Evaluation of VSAT-QPSK System.
[9] Norishima, K., Koizumi, T., Motoyoshi, M., Kameda, S., & Suematsu, N. (2016, December). Demodulation characteristics of a 20GHz-band direct RF undersampling receiver. In 2016 Asia-Pacific Microwave Conference (APMC) (pp. 1-3). IEEE.

[10] Sesena, J., & Prieto, H. (1995). Satellite digital TV reception through domestic TV networks (SMATV).
[11] Kumar, K. V., & Balakrishna, R. (2013). Supervisory control and data Acquistion (SCDA) in sub transmission and distribution levels in power systems.
[12] Misran, S., Norman, A. A., & Hamid, S. Continuous Auditing (CA) Integration with Big Data Analytics to improve FFB Yield performance for Plantation Company.
[13] Karthikeyan, S., & Bhuvaneswari, P. T. V. (2017, January). Iot based real-time residential energy meter monitoring system. In 2017 Trends in Industrial Measurement and Automation (TIMA) (pp. 1-5). IEEE.
[14] Sahani, B., Ravi, T., Tamboli, A., & Pisal, R. (2017, April). IoT Based Smart Energy Meter. In International Research Journal of Engineering and Technology (IRJET) (Vol. 4, No. 04, p. 96).
[15] Thakare, S., Shriyan, A., Thale, V., Yasarp, P., & Unni, K. (2016, December). Implementation of an energy monitoring and control device based on IoT. In 2016 IEEE Annual India Conference (INDICON) (pp. 1-6). IEEE.
[16] Hiwale, A. P., Gaikwad, D. S., Dongare, A. A., & Mhatre, P. C. (2018). Iot Based Smart Energy Monitoring. power, 5(03).
[17] Zafar, R., Mahmood, A., Razzaq, S., Ali, W., Naeem, U., & Shehzad, K. (2018). Prosumer based energy management and sharing in smart grid. Renewable and Sustainable Energy Reviews, 82(1), 1675-1684.
[18] Bhilare, R., & Mali, S. (2015, December). IoT based smart home with real time E-metering using E-controller. In 2015 Annual IEEE India Conference (INDICON) (pp. 1-6). IEEE.
[19] Surekha, T. P., Ananthapadmanabha, T., & Puttamadappa, C. (2012). C-band VSAT data communication system and RF impairments. arXiv preprint arXiv:1206.1722.
[20] Tongia, R. (2003). The political economy of Indian power sector reforms. *Program on Energy and Sustainable Development Working Paper*, 4(1), 1-10.
[21] Tongia, R. (2003). The Political Economy of Indian Power Sector Reforms, WP 4, Program on Energy and Sustainable Development.
[22] Schwieters, N. O. R. B. E. R. T., & Flaherty, T. (2015). A Strategist's Guide to Power Industry Transformation. Forbes, September.
[23] Kumar, A., & Prakash, A. (2014). The role of big data and analytics in smart cities. *Int J Sci Res (IJSR),* 6(14), 12-23.
[24] Rezaienour, J., & Nazaridoust, M. (2012, December). Data Mining application in analysis of Knowledge management gaps. In Proceeding of the 2nd World Conference on Soft Computing (pp. 551-557).
[25] Sengupta, R., Heeks, R., Chattapadhyay, S., & Foster, C. (2017). Exploring big data for development: an electricity sector case study from India. In Association of Information Systems pre-ICIS SIG GlobDev Workshop, Seoul, South Korea.
[26] Olszak, C. M. (2014). An overview of information tools and technologies for competitive intelligence building: theoretical approach. Issues in Informing Science and Information Technology, 11(1), 139-153.
[27]"Big Data" Initiative as an IT Solution for Improved Operation and Maintenance of Wind Turbines
[28] Boyer, S. A. (2009). SCADA: supervisory control and data acquisition. International Society of Automation.
[29] Igure, V. M., Laughter, S. A., & Williams, R. D. (2006). Security issues in SCADA networks. *Computers & security,* 25(7), 498-506.
[30] Krutz, R. L. (2005). Securing SCADA systems. John Wiley & Sons.
[31] Ten, C. W., Liu, C. C., & Manimaran, G. (2008). Vulnerability assessment of cybersecurity for SCADA systems. IEEE Transactions on Power Systems, 23(4), 1836-1846.
[32] Miller, B., & Rowe, D. C. (2012). A survey SCADA of and critical infrastructure incidents. RIIT, 12(1), 51-56.
[33] Depuru, S. S. S. R., Wang, L., Devabhaktuni, V., & Gudi, N. (2011, March). Smart meters for power grid—Challenges, issues, advantages and status. In 2011 IEEE/PES Power Systems Conference and Exposition (pp. 1-7). IEEE.
[34] Benzi, F., Anglani, N., Bassi, E., & Frosini, L. (2011). Electricity smart meters interfacing the households. IEEE Transactions on Industrial Electronics, 58(10), 4487-4494.
[35] Zheng, J., Gao, D. W., & Lin, L. (2013). Smart meters in smart grid: An overview. In 2013 IEEE Green Technologies Conference (GreenTech) (pp. 57-64). IEEE.
[36] Venables, M. (2007). Smart meters make smart consumers. Engineering & Technology, 2(4), 23-23.
[37] Hemanth, C. K., & Panigrahi, S. R. (2018). A Study on Financial Statement Analysis of Karnataka Power Transmission Corporation Limited-KPTCL, Bangalore.
[38] Mylona, A., Carr, S., Aller, P., Moraes, I., Treisman, R., Evans, G., & Foadi, J. (2017). A novel approach to data collection for difficult structures: data management for large numbers of crystals with the BLEND software. Crystals, 7(8), 242.
[39] Rathod, T. G. Management of Power Generation Projects in Karnataka: A case study of KPCL.
[40] Srinivas, K. T. (2013). A study on working capital management through ratio analysis with reference to Karnataka Power Corporation Limited. National monthly refereed journal of research in commerce & management, 2(1), 12-80.

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