DEVELOPMENT OF A COST-EFFECTIVE, SMART EARLY WARNING SYSTEM FOR IMPROVING THE RELIABILITY OF ELECTRICAL SUBSTATIONS

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ABSTRACT

This research paper discusses the development of an innovative system which has been developed in collaboration with the power industry, to improve the reliability of substations. It presents a remote fault detection and identification system for a substation to minimize failures and their effects using innovative hardware and software system integration. This early warning system has been developed to improve the reliability of substations, enables the authors to mitigate possible negative consequences of power system operation. It is a cost-effective alternative solution prior to IEC6150 based substation automation system is implemented in the developing countries. The equipment developed for this purpose has several advantages: low cost, low power consumption and easy installation & maintenance. In this paper, the authors share their success stories and lessons learned in the implementation of their system to improve the reliability of electrical substations. Improvements in the Reliability indices have been compared before and after the commissioning of the early warning system.

Keywords: Early Warning System, Power Systems, Smart-Grid, Reliability Improvement, IEC61850, Generic Objective Oriented Substation Events.

I. INTRODUCTION

Electrical systems failure depends on factors such as loads, redundancies and configurations. There are different mathematical models to evaluate the reliability of existing power systems, but none of the existing models provide a practical workable solution to improve the reliability. The aim of this research is to develop an advanced early warning system which is practically efficient and accurately evaluate the reliability of the existing and future Smart-Grid applications of power systems. Not enough research is there in the area of natural disaster and power system failure early warning systems for Australian energy sector. In references [1-3] impact of natural disaster on power systems is presented. Natural disaster early warning system for power systems was proposed in reference [4] which consists of early warning monitor, risk assessment and early warning system. The main disadvantages of this system are: 1. Expensive to build, install and maintain 2. Cannot detect the fault location in power systems. Electrical power utilities are faced with an aging infrastructure with an increasing risk of blackouts and brownouts. As a consequence, utilities are looking for ways to address these issues in order to improve the reliability of electrical power delivery while at the same time reducing unplanned maintenance costs. Power industry all over the world is looking for the ways to improve the reliability of supply to its customers by investing hugely on its infrastructure. The most important part of reliability improvement is monitoring. Monitoring includes recording root causes and assets affected

during outages and how well the process of restoring supply is managed. Some commonly used substation reliability indices are : Failure rate per year, failure duration (min/year), Repair time r (hours) and Availability(%). Reliability indices such as System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), and Average Service Availability Index (ASAI) are measures of supply wide reliability, operation and maintenance efficiency. The proposed hardware solution is cost effective and detects the faults and tansmits the information. This system monitors the condition and status of the critical components of power systems and based on the collected data estimate the chance of component failure during normal and extreme weather conditions, as well as during natural disasters period. A Site Condition Manager (SiCOM) is an SMS based system for detection and intimation of faults/Alerts/Alarms generated in various critical equipment such as circuit breakers, integrated power supplies, UPS, battery chargers, battery banks, generator panels is used in this research, to monitor and improve the reliability of test beds. After successfully testing on a test bed, this system has been deployed in railways, ATM security, Telecom exchanges and in Transmission sub-stations. By using this technology, this research is trying to increase the power system reliability and maintainability by providing more awareness to the operator of the impending failures in the system. This concept is considered to be an implementation of the Smart Grid philosophy. One of the advantage of the planned approach is to bring more awareness of the system stressed points and the potential to avert outages. Consequently, more secure operation and a more reliable system is possible. The remainder of the paper is organized as follows: Section 2 provides case study of substations. Here author describe the key issues, solutions and the results. Section 3 Illustrates an example of data collected from EWS and reliability. Section 4 discusses about Cost, Finally section 5 provides the conclusions and the directions for future work.

II. CASE STUDY: SUBSTATIONS

The strongest point in the power system is the electrical substation and it is also the weakest point or place of failure that is leading to the loss of load. Inside a Power System Substation, there are several components: generators, step-up transformers, step-down transformers, compensating coils, overhead lines, underground cables, disconnecting switches, circuit breakers, voltage transformers, current transformers, and surge arrestors. In this paper, any fault occurring on those components that will lead to a protection system response is defined as initiating fault. There are several methods that can be used for the reliability evaluation of the substations. The mostly used reliability evaluation methods are fault tree analysis, event tree analysis, Monte Carlo simulation and State enumeration. To study the static reliability, fault tree analysis, Monte Carlo simulation and State enumeration are used frequently. When it comes to the dynamic reliability evaluation, event tree analysis and Sequential Monte Carlo are better choices. In this paper different hardware solutions is investigated and the authors are proposing the development of a Cost-Effective, Smart Early Warning System for Improving the Reliability of Electrical Substations. By the use of thermal imaging cameras and automation software, power industry has developed monitoring systems that provide early warning of impending equipment failures such as transformer fluid leaks or internal insulation breakdown. These thermal imaging cameras can recognize differences in the heat signatures of electrical components and the surrounding background, and compare the temperatures of similar components in close proximity to one another.Thermal Imaging can improve the reliability of substation up to certain extent but there are several disadvantages of thermal imaging: A lot of cameras need to be installed to cover a large perimeter, limited detection at night, Light illuminates only certain small area, limited capabilities in fog and rain, high power consumption, high maintenance cost and can’t

monitor electrical characteristics. Another method to improve the reliability of power system is Substation automation. Substation Automation Systems (SASs) are widely used for the purpose of control, protection, monitoring, communication etc. in substations to improve the reliability of the power system [5]. The SAS is a system that provides the automation functions for monitoring, control and protection within a substation and utilizes recent improvements in the fields of electronics, information and communication technologies. SASs based on IEC 61850 is increasing. The main objective of the recently published standard, IEC 61850 is to facilitate interoperability and it aims to enable logical configuration of the SAS by connecting various types of equipment from different vendors through an Ethernet LAN [8]. There are several implementation issues with IEC 61850 based Substation Automation Systems such as 1. Process Bus Issues, 2.Station Bus Issues, 3. Overall SAS Functional Issues and 4 .Planning Issues. Developing countries are slow in implementing SAS, meanwhile power companies are looking for interim hardware solutions to improve the reliability of substation. The solution provided in this paper will meet the needs of power companies in developing countries. Key issues in Electrical Power Utilities in developing countries such as India, Pakistan, Bangladesh, Sri Lanka, Nepal, Bhutan and etc., is increasing risk of black outs and brownouts. This along with increasing unplanned maintenance costs and ever increasing demand for uninterrupted power supply to the consumer, it becomes highly important to instantly communicate the outage status in the substation to the staff so that the fault rectification can be done as soon as possible and minimize monetary losses. The proposed solution is that the outage status of each transmission element is intimated through SMS to the concerned personnel. The major elements which are monitored are Circuit Breakers, Protection Relays, Auto reclose relays. EWS with up to 32 Digital inputs (expandable up to 64) and up to 16 Analog input channels, effectively makes use of the existing GSM Network for communication. The built-in microcontroller continuously keeps watch on various digital as well as analog inputs which are in turn connected to the Relays and CBs and various voltage, current lines and other vital elements of the substations through transducers or signal conditioners. As a result of this proposed solution, several Early Warning Systems (EWSs) commissioned in various substations across India viz., Warangal, Nellore, Vizag, Hyderabad (Andhra Pradesh), Trichy, Hosur (Tamil Nadu), Wardha (Maharashtra), Baroda/Jambuva(Gujarat), etc. Power grid 400/220kV substations and 220kV transmission corporation substations are successfully running and helping the maintenance staff in keeping themselves informed on the malfunctioning of various substation elements and thus optimizing their maintenance costs, average interruption frequency and interruption duration were reduced.

Figure 1: Typical 400KV Substation At A Place Called Warangal In India, The Control Room And The Installed EWS In Shown. An SMS Sent From the Device Can Also Be Seen In the Picture Above

- **HVDC-VIZAG: ICT-1 GR-A/B Operated on 2012/07/10,21:00:03:45.**
- **HVDC-VIZAG: ICT-1 GR-A/B Restored on 2012/07/10,2100:15:25.**
- **HVDC-VIZAG: Kalapaka-1 GR-A/B Operated on 2012/07/11,15:40:57:50.**
- **HVDC-VIZAG: Kalapaka-1 GR-A/B Restored on 2012/07/11,15:41:15:40.**
- **HVDC-VIZAG: BUSBAR-2 Protection Operated on 2012/07/11,15:40:58:95.**
- **HVDC-VIZAG: BUSBAR-2 Protection Restored on 2012/07/11,16:56:58:55. After 1 hrs. 16 mins.**
- **HVDC-VIZAG: 400 KV BPL-2 TIE CB Operated on 2012/07/11,15:40:58:10.**
- **HVDC-VIZAG: 400 KV BPL-2 TIE CB Restored on 2012/07/11,15:41:25:30.**
- **HVDC-VIZAG: 220 KV DUR-2 LINE CB Operated on 2012/07/11,15:40:58:95.**
- **HVDC-VIZAG: 220 KV DUR-2 LINE CB Restored on 2012/07/11,15:40:58:10.**

Sent Massages:**Command**: admin123 set port 02,1,1, 220 KV NGM-2 LINE CB Operated, , 220 KV NGM-2 LINE CB Restored

Response: SUCCESS setport 02,1,1, 220 KV NGM-2 LINE CB Operated, , 220 KV NGM-2 LINE CB Restored.

Figure 2: Sample Data from an Electrical Substation at A Place Called Vizag in India

III. RESULTS

The Power Grid Corporation of India has reduced: frequency of interruption per year, number of circuits interruptions per year and outage duration minutes per outage, in all eight substations where this EWS installed.

IV. COST

Cost effectiveness of EWS as compared to any other solution provided by other industry partners in the Power Industry is excellent. Similar systems in power industry are typically large scale SCADA systems with RTUs (Remote Terminal Units) for which lot of hard Copper wiring is to be done, huge infrastructure and several software protocols are involved [6]. Proposed EWS is a miniature RTU, with onboard communication mechanism; this is a simple plug and play type device, for less than A$1000 and works on 12 Vd.c. Hence, this system works out to be power efficient, highly portable and cost effective.

V. CONCLUSIONS

In this paper, a cost-effective early warning system for improving the reliability of power systems is demonstrated using substation case studies. Improvement in Reliability indices were identified before and after the installation of EWS. This Early Warning Systems offer great advantage in efficient maintenance and fault handling in power systems. Though this research work throws light on the developments that have happened to date, the future holds great potential for this system in terms of, integration with weather monitoring equipments, Digital Fault Recording, failure prediction and preventive maintenance. This system can be further improved in future research to integrate the design of electrical substation automation. It can be improved to meet IEC61850 standard and generate Generic Objective Oriented Substation Events (GOOSE) messages [7] in a more user friendly manner.

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