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Concept of Automation in Management of Electric Power Systems

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Abstract**—**An electric power system includes a generating, a transmission, a distribution, and consumers subsystems. An electrical power network in Tanzania keeps growing larger by the day and become more complex so that, most utilities have long wished for real-time monitoring and remote control of electrical power system elements such as substations, intelligent devices, power lines, capacitor banks, feeder switches, fault analyzers and other physical facilities. In this paper, the concept of automation of management of power systems from generation level to end user levels was determined by using Power System Simulator for Engineering (PSS/E) version 30.3.2.

Keywords**—**Automation, Distribution subsystem, Generating subsystem, PSS/E, TANESCO, Transmission subsystem.

I. Introduction

POWER system automation is an act of controlling the power system automatically by deploying appropriate instrumentation and control in the system. Power system automation includes monitoring, evaluation, analysis, and control of processes associated with generation and of delivery systems of power from power stations to customers. Further, power system automation consists of three major processes, namely, data acquisition, power system supervision and power system control all working in a coordinated automatic fashion. Data acquisition refers to collecting data in the form of measured analog current or voltages values or the open or closed status of contact points. Power system supervision is carried out by operators and maintenance engineers through this acquired data either at a remote site represented by computer displays and graphical wall displays or locally, at the device site, in the form of front-panel displays and laptop computers. Control refers to sending command messages to a device to operate I&C (a collect of devices that monitor, control and protect the system is referred as I&C system) and power system devices [1], [4], [6].

Electric power utilities worldwide are increasingly adopting the computer aided monitoring, control and management of electric power distribution systems to reduce cost of operations, maintenance and services and to provide better services to electricity consumers [5]. Reliable on-line information acquisition, remote control and efficient power system management are increasingly becoming a requirement by electric power utility companies. As power networks become larger and more complex, power sources increase, control and power devices spread over larger geographical areas that are sometimes hostile. Considering the extensive size of the power supply network for a national grid system and some micro grids, centralized information on health of the network and devices, remote control and servicing of network, customers and power sources can be achieved by utilizing information technology taking advantages of available computer computation and storage power and high-speed of communication and the different technologies available. The system of monitoring and control of electric power distribution networks is also called ‘‘Distribution Automation System (DAS)” [5].

The Institute of Electrical and Electronic Engineers (IEEE) has defined DAS as a system that enables an electric utility to remotely monitor, coordinate and operate distribution components in real-time mode from remote locations [2]. The distribution automation system is based on an integrated technology, which involves collecting data and analyzing information to make control decisions, implementing the appropriate control decision in the field and also verifying that the desired result is achieved [3].

II. Status of Electrical Power Network in Tanzania

Currently, Electric power system network in Tanzania is using for transmission 220kV (2,861 km), 132kV (1,528 km) and 66kV (546 km) voltage levels. The short term planned extension of transmission network is 132kV (366 km), 220kV (993 km), 300kV (DC) (1,000 km) and 400kV (2,249 km). The transmitted voltage is stepped down to medium voltages of 11kV (6,392 km) or 33kV (14,141 km) for primary distribution and to feed substations for stepping down to 380/230V (34,157 km) for the secondary distribution network to supply customers with 3-phase and/or 230 for residential, commercial or industrial use at present. The electrical power utility company in Tanzania the Tanzania Electric Supply Company (TANESCO) operates distribution networks in most of the urban and in some of the rural areas. This is a substantial investment for a developing country like Tanzania whose utilization must be optimized to support economic development by ensuring its delivery is efficient and reliable and of required quality at all times.

The power utility company (TANESCO) has implemented power system automation in some of its electric power stations and in the high voltage transmission sides but not in the medium and low voltages transmission sides of the network. As a result, various distribution activities such as monitoring

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(of distribution transformers, meter reading, rotten wooden poles for replacement, transmission conductors, etc), coordination (of voltages by maintaining and adjusting voltage levels) and operation (of recording metering, construction and planning of new service lines, line maintenance by upgrading or re-conductoring, attending customers' complaints, etc) of medium voltage transmission network and for medium and low voltage distribution are done manually. At the moment, to obtain information on the status of the TANESCO electric supply network and systems, staff either conduct surveys on distribution areas or receive notification from customers reporting faults in the affected areas. This approach is expensive and creates misunderstanding between TANESCO staff and the company and its consumers, especially in the event of blackout, low voltage, voltage fluctuation, intermittent faults, etc when these anomalies/ malfunction/ faults remain un-attended for long periods of time. Furthermore, the system does not provide information on illegal tempering of customer connections or illegal usage of the power utility resources.

The DAS can, besides what was mentioned earlier, be used to monitor the quality of the supplied electrical power. It is important to monitor the quality of supplied power from economic point of view. This is because poor power quality affects the performance and life span of equipment connected to it such as transformers, equipment using motors, circuit breakers, etc, whose reliability depends on being supplied with stable rated power supply. The lack of quality power can result into mis-operation and damage to equipment thus resulting into disruption of operations and other anomalies.

The electrical power system network have been extended to rural areas and the current government drive is to raise it from 70% to over 30% by 2015 and 75% by 2025 which will make the rural network extensive. The rural network has rough terrain making frequent surveys even less likely, particularly during the rainy season when incidents are more frequent and many roads are not readily passable making survey even more challenging. Therefore, the TANESCO emergency repair and maintenance response team will rely on customer reporting failures and feasibility to access network facilities at respective sites.

It is therefore necessary for TANESCO to use power system automation in its entire network including the low and medium voltages networks to reduce operation costs and response time since everything will be done automatically remotely, timely and will provide better services to consumers. This is essential to gain higher level of customer satisfaction which is rather low at present.

Therefore, the use of automation to monitor, control and manage power system shall facilitate a reduction in activities and the need for staffs to make long journey to survey the power network and its systems saving staffs time and transport costs. Furthermore, failure/faults can be observed timely to facilitate timely corrective action. This problem is in the entire distribution (medium and low voltages including consumers) network which is extensive. Therefore, this is a realistic challenge since it is the largest network which is growing very fast and affects directly customers connected to the network. However, one of the principle components in the automation of management of the electrical power network is communication. Monitored information must be transmitted to processing centers and commands be sent to network devices.

TANESCO therefore has to use appropriate communications technique on the electrical power distribution systems to perform actions like reading the electricity meter, monitoring the power consumers, finding faults along the systems, detecting illegal electricity usages etc. There are a number of communication technologies options available today which includes wireless networks like mobile operators' services, cognitive radio etc. satellite and optical fiber. TANESCO has an additional option to use its power line network to provide communications to facilitate their internal and external communications.

With power system, automation utility companies can implement flexible control of transmission and distribution systems, which can be used to enhance efficiency, reliability and quality of electrical service while optimizing operational costs. Flexible control also results in more effective utilization and life-extension of the existing distribution system infrastructure [5].

The objective of this paper is to determine the concepts of automation of management of electrical power systems from generation points to end users.

III. Concepts of Automation of Electrical Power Systems

The proposed conceptual model for automation of management of electrical power network is illustrated in Fig. 1. The concept of automation of electrical power system exchange information among different communication domains. The proposed conceptual model shows that there are two strings of flowing of information in Fig. 1, one for power flow information and another for remote monitoring and control stations.

A. Power Flow String

The power flow string communication domains consist of generation level, substations level, transmission level, distribution level and, end users level. At the power generations, automation includes the ability to check generated reactive power, active power, power factors, root mean square value of voltage and current, frequency variation etc. At the Transmission line, automation includes the ability to check fault location, circuit breaker, bus-bar isolation, line isolation, falling of power poles etc. At the transformers, automation includes the ability to check oil level, over-current, voltage control, transformer trip etc. At the substations and feeders, automation includes supervisory control of circuit breakers, load tap changers, regulators, re-closers, sectionalizers, switches and substation capacitor banks etc. Remote data acquisition is required in order to achieve effective use of the supervisory control function. At the end users location, automation includes the ability to remotely: read meters, connect/disconnect services and control consumer loads etc.

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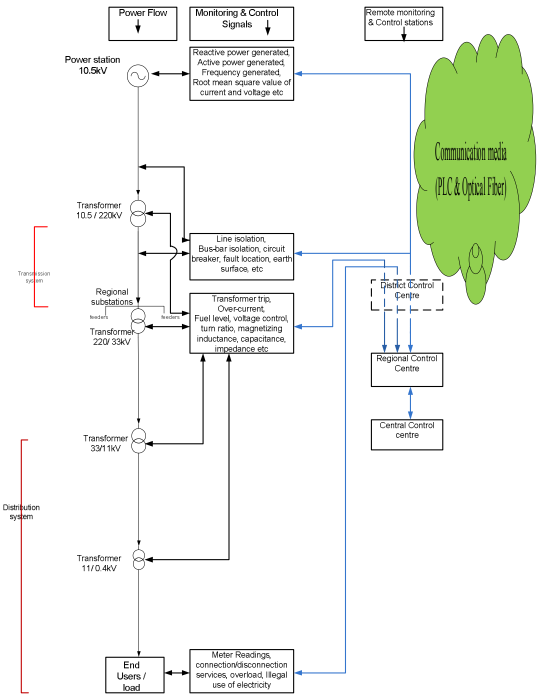

Fig. 1 The proposed concept of automation of power system

Power System Automation allows for automatic, computerized control of utility power network facilities. Automation system allows power generation, transmission systems and distribution system to be monitored and controlled from a remote location, even if they were far away from the systems location.

B. Monitoring and Control Stations

The remote monitoring and control stations string communication domains consist of main control center, regional control center and district control center. Due to increase in network activities the primary monitoring and control center is needed at the district control level.

Data is collected along the power network, transferring data to a regional control centre and then to central control centre, displaying the data and carrying out analysis for control decision and improvement in system operation.

C. Communication Systems

Communication can be generally defined as transfer of information from one point to another or from source to destination or from transmitter to receiver. The interchange of data between any two devices across a communication channel involves using some type of electrical signal which carries this data. Fig. 1 shows the two-way communication interfaces among the communication domains of the strings of power flow and monitoring and control center stations. Effective communication can be optical fiber and power line communication or wireless communication.

D. Monitoring and Control Signals

The electrical parameters (e.g. root mean square values of voltage and current, frequency, active power etc.) and other various quantities (e.g. switch status, winding temperature, oil level, over-current, overload, meter readings etc.) are recorded in the field at the power stations, transformers, substations, feeders and consumer location using a data acquisition device called Remote Terminal Unit (RTU). These quantities are transmitted to a regional computer control and then to central computer control through a communication media.

The importance and significance of collecting data along power network and storing data in data storage facility systematically (Monitoring system) was emphasized in this work. It is through monitoring system that utility company can capture data, process and disseminate information in a systematic way for the intended purposes. This forms the heart of automation to achieve optimal power system performance and effective energy management and to reduce operational costs and provides better service to consumers.

The useful functions of the network monitoring system is to provide alarm to operator and register when something is wrong, slow or failing systems and notify the utility operator such occurrences. Typical facts that network monitoring should provide alert to a utility operator includes system overload, over-current, transformer trip, transformer oil level, lost network connections, power outages, tempering attempts, etc. Hence, Significance of network monitoring in network management is pegged on three goals in network management: perform monitoring, fault monitoring and account monitoring. It will assist in finding network trends and locate network problems quickly.

Therefore, due to advancement in the communication technology, ensures that information and status of network elements and control signals can be transported, processed, displayed/ acted on reliable for remote operation manually or automatic. Therefore, automation is no longer for operation of power stations only but can be extended to cover transmission system, substation and distribution system reliably.

IV. Monitoring Simulation Tool

There is a number of power monitoring tools in the market, however the one that was available to researcher of this paper was PSS/E software. The selection of PSS/E software was based on availability constraint; however it provided a sound testing vehicle for management of automation.

The aim was assessing the concepts of automation of management of electrical power systems, using simulations which were conducted using PSS/E simulation tool.

A. Simulation Parameters and Results

There are many power systems parameters but for the purpose of this work, the simulation parameters were limited to two; load flow and short circuit conditions. These were selected because load flow and short circuit conditions are parameters which are significant in faulty conditions.

During PSS/E simulation for load flow and short circuit conditions, an electrical line diagram in Fig. 2 was assumed. The generator in Fig. 2 was been assumed to have a base voltage of 0.4 kV and generates active power and reactive powers of 3.6 MW and 2.4 MVAR. The maximum active and reactive powers generated by the generator in a diagram are 10 MW and 2 MVAR and minimum active and reactive power are 0MW and -2MVAR.

B. Power Flow/Load Flow

Power Flow/ Load Flow is an important tool involving numerical analysis applied to power system. It analyzes the power systems in normal steady-state operation. Furthermore, it focuses on various forms of Alternating Current (AC) power such as voltages, voltage angles, real power and reactive power.

In Fig. 2, the bus bars number one, nine and twelve (No-1, No-9 and No-12) have voltage 0.4 kV, the bus bars number two, three and four (No-2, No-3 and No-4) have voltage 33 kV, the bus bars number five and eight (No-5 and No-8) have voltage 11 kV and the end arrow lines indicate that lines are connected to users/load. The numbers with decimal points that are shown along the line diagram are the active and reactive power of the lines.

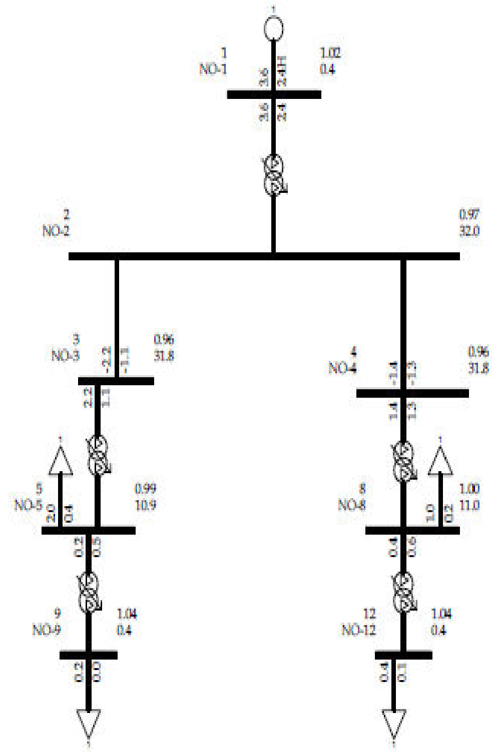

Fig. 2 Electrical line diagram

The simulation of data in Fig. 2 showed that the active and reactive power generated were 3.6 MW and 2.4 MVAR, the maximum active and reactive power were 10MW and 2MVAR with the minimum active and reactive power of 0 MW and -2 MVAR. These results indicate that, the system had no problems.

The loads connected in bus bars numbered 5,8,9 and 12 in Fig. 2 were assumed to have capacity of (2, 0.4), (1, 0.2), (0.2, 0.04), (0.4, 0.08), where the first number inside a bracket is the active power measured in MW and the second number the reactive power measured in MVAR. Further, the simulation was conducted using Fig. 3 where the load capacity in Fig. 2 were increased to (7.222, 2.3738), (3.6111, 1.1869), (0.7222, 0.2374), (1.4444, 0.4748) respectively. The simulation of data in Fig. 2 showed that the colour of bus bar numbered 2, 3, 4, 5, 8, 9 and 12 changed from black colour to green colour indicating that bus bars numbered 2, 3, 4, 5, 8, 9 and 12 are overload.

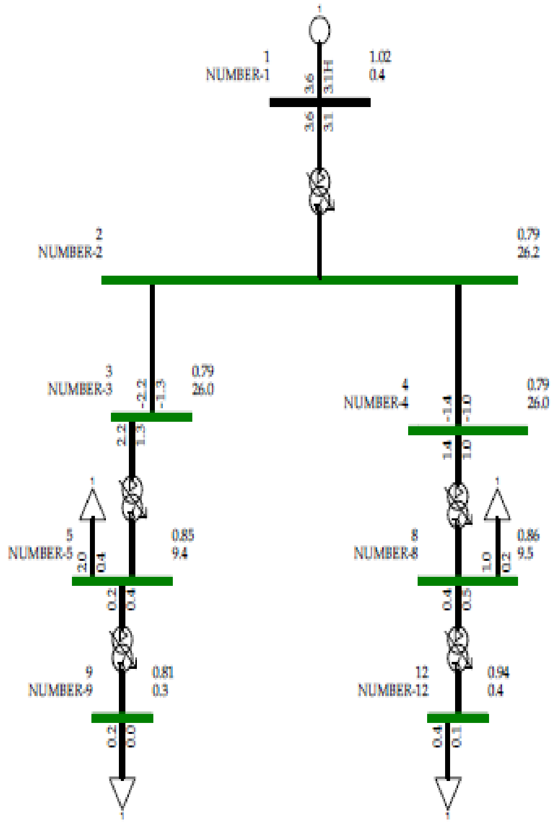

Fig. 3 Electrical line diagram with increasing the capacity of loads

C. Short Circuit Condition

Short Circuit is an electrical circuit that allows a current to flow along an unintended path, where no or a very low electrical impedance is encountered. In circuit analysis, the term short circuit is used by analogy to designate a zero impedance connection between two nodes. This makes the two nodes to be at the same voltages. The simulation of three phase short circuit fault analysis conducted using configuration and load conditions in Fig. 2 and the output is shown in Fig. 4.

During simulation researcher selected bus bar number 8 to introduce three phase short circuit fault condition for analysis resulting in large amount of current to bus bar number 8 compare to the others. Such conditions can be monitored by the communication channels which connect components in the power network and the control centre. Utility operator at the control centre will automatically get notification and send report to required section for control decision.

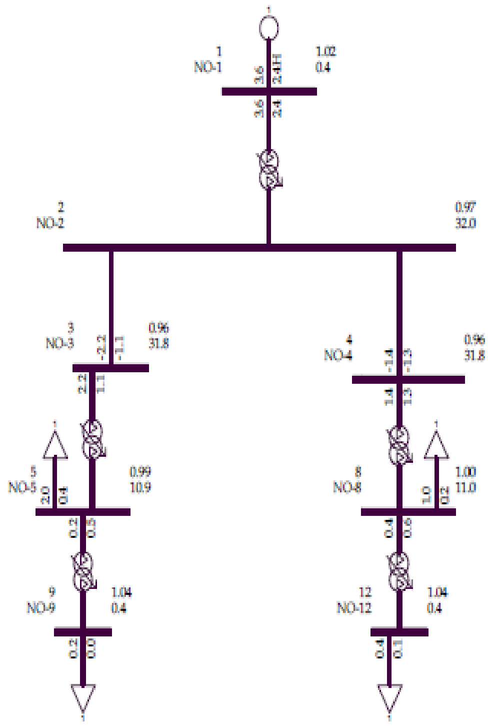

Fig. 4 Three phase short circuit fault analysis line diagram

V. Conclusion and Recommendations

The concepts of automation of power system management from generation point to end users were presented and simulation results were shown. With respect to the simulation conducted and output where shown for configuration and condition given in Figs. 2-4, the aim was to show what the utility operator at the control centre will view from an automatic management system for power networks indicating its using monitoring software. This was necessary since it could not be done on an actual network. It also serves facility for operators of a real time system. Therefore, whenever problem concerning power network occurs the utility operator will automatically get indication and send report to required department for control decision.

It recommended to utility companies such as TANESCO to use automation of power system in its whole network i.e. from generation to distribution network to reduce number of activities as everything will be done automatically and will provide better services to consumers. As power network is large and more complex thus, the use of automation facilitates reduction of operational cost and the need for staffs to make long journey to survey the power network.

It also noted that the use of automation provides better real time monitoring and remote control of system elements such as substations, intelligent devices, power lines, capacitor banks, feeder switches, fault analyzers and other physical facilities.

It is further recommended to use automation of power system to offer remote supervision and control of switches, such as pole mounted switches and pad-mounted switchgears on medium voltage distribution networks. It can also offer automatic isolation of faulty sections, which allows quick and accurate recovery of a stable power supply, and reduces the out of service areas by unit of distribution sections.

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