POWER AFRICA
NIGERIA POWER SECTOR PROGRAM
EMS/SCADA AND COMMUNICATION IN NIGERIA

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<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>ACE</td>
<td>Area Control Error</td>
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<td>AGC</td>
<td>Automatic Generation Control</td>
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<td>CIM</td>
<td>Common Information Model</td>
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<tr>
<td>DTS</td>
<td>Dispatcher Training Simulator</td>
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<td>EDF</td>
<td>Électricité de France</td>
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<tr>
<td>EMS</td>
<td>Energy Management System</td>
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<tr>
<td>FGN</td>
<td>Federal Government of Nigeria</td>
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<tr>
<td>GW</td>
<td>Gigawatts</td>
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<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
</tr>
<tr>
<td>HVAC</td>
<td>High Voltage Alternating Current</td>
</tr>
<tr>
<td>HVDC</td>
<td>High Voltage Direct Current</td>
</tr>
<tr>
<td>ICCP</td>
<td>Inter-Control Center Communications Protocol</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers Standards</td>
</tr>
<tr>
<td>LFC</td>
<td>Load Frequency Control</td>
</tr>
<tr>
<td>MHI</td>
<td>Manitoba Hydro International</td>
</tr>
<tr>
<td>MVAR</td>
<td>MegaVolt Ampere Reactive</td>
</tr>
<tr>
<td>MW</td>
<td>Megawatt</td>
</tr>
<tr>
<td>NANERC</td>
<td>North American Electrical Reliability Corp</td>
</tr>
<tr>
<td>NCC</td>
<td>National Control Center</td>
</tr>
<tr>
<td>NEPA</td>
<td>National Electric Power Authority</td>
</tr>
<tr>
<td>NIPP</td>
<td>National Integrated Power Projects</td>
</tr>
<tr>
<td>PA-NPSP</td>
<td>Power Africa – Nigeria Power Sector Program</td>
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<tr>
<td>PLCC</td>
<td>Power Line Carrier Communication</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
</tr>
<tr>
<td>PLS</td>
<td>Party Line System</td>
</tr>
<tr>
<td>PMO</td>
<td>Project Management Office</td>
</tr>
<tr>
<td>PSSE</td>
<td>Power System Simulator for Engineering</td>
</tr>
<tr>
<td>RTU</td>
<td>Remote Terminal Units</td>
</tr>
<tr>
<td>SAS</td>
<td>Substation Automation System</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SNCC</td>
<td>Supplementary National Control Center</td>
</tr>
<tr>
<td>TCN</td>
<td>Transmission Company of Nigeria</td>
</tr>
<tr>
<td>TEM</td>
<td>Transitional Electricity Market</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply</td>
</tr>
<tr>
<td>VAR</td>
<td>Volt-amps-reactive</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

PURPOSE OF THIS ASSESSMENT

An Energy Management System (EMS)/Supervisory Control And Data Acquisition (SCADA) and communication system is synonymous with the best practices in operation, control, and analysis of a modern electrical power system comprising of generating stations, and the transmission and distribution network supplying electrical power to various forms of loads.

While the power sector in Nigeria has various issues, in the absence of a robust EMS/SCADA and communication system, the Transmission Company of Nigeria (TCN) is experiencing a major hurdle connecting and communicating to all of the sub-stations and generating stations on a real-time basis. This has contributed to the country’s power system experiencing multiple system blackouts each year. With the Transitional Electricity Market\(^1\) (TEM) in force, it is very important to obtain both real-time and historical data of all the power flows and energy meter readings in an accurate and timely manner. Without an EMS/SCADA in place, obtaining the necessary data of power flow transactions which have a huge financial implication, and coming up with the electricity market settlement for the generation companies (GENCOs), distribution companies (DISCOs), and TCN, is a challenge. Further, due to the absence of this system, there is no effective database available to carry out power system studies which is required to holistically run the present network or plan for the expansion of the network across the country. This in its entirety has created stress for the system operators as all operations have to be carried out manually without a real-time view of the system.

Nigeria has made several attempts to set up an effective EMS/SCADA system. The chronology of projects which date back to before 1990, has never been able to achieve its full objective thus leaving the system operators bereft of the most reliable tool to control, operate, and analyze the power system of the country in an effective and optimal manner.

This report details:

- The history of prior EMS/SCADA implementation attempts in Nigeria.
- The current state of the entire power system in Nigeria.
- The state of an EMS/SCADA and communication system that is expected in Nigeria and necessary for the Nigerian power system in conjunction with global best practices.
- The steps to achieve a modern EMS/SCADA to cover the entire power system with the option to cater to expansion of the power system in the future.

This report has been developed based on research and historical data contained in previously available reports completed by external consultants engaged by TCN, in addition to information on the TCN system operation department website and important discussions with relevant TCN staff.

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\(^1\) TEM is a contract-based transaction of power from GENCOs to DISCOs through TCN, based on vesting contracts between DISCOs and NBET and Power Purchase Agreements (PPA) between NBET and GENCOs. Daily power flow schedules are prepared based on the declaration of availability by GENCOs and requisition by DISCOs. All deviations from these schedules are intended to be penalized by the Market Operator in the monthly invoices.
INTRODUCTION: OVERVIEW OF EMS/SCADA AND COMPONENTS

ENERGY MANAGEMENT SYSTEM

The EMS is a complex computer system of hardware and a series of specific power system applications that are used by system operators for real-time operation and control of a power network, comprising generating stations and transmission and distribution network equipment in a coordinated manner. Besides monitoring and controlling the power system, the EMS enables the system operators to make logical, technical, and commercial decisions so that quality power is delivered in a reliable and cost effective manner, while also managing any contingency in the particular network, thereby optimizing the performance of the entire power system. The EMS is normally located in the main control center and the emergency control center. Table 1 provides an overview of the major uses of a modern EMS.

Table 1: Main Uses of a Modern EMS

<table>
<thead>
<tr>
<th>EMS Uses</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor network elements</td>
<td>To monitor, control, and operate the network elements like circuit breaker, isolator, generator etc. at generation, transmission and distribution on real-time basis remotely.</td>
</tr>
<tr>
<td>Monitor network parameters</td>
<td>To monitor and control the network parameters like voltage, frequency, MW, and MVAR on real-time basis remotely.</td>
</tr>
<tr>
<td>Network analysis</td>
<td>To use the data to carry out various forms of network analysis and verify with power system study models.</td>
</tr>
<tr>
<td>Load balancing</td>
<td>To monitor load sheds and take corrective action to manage the load on the entire system.</td>
</tr>
<tr>
<td>Record keeping</td>
<td>To maintain historical records for sequence of events in respect of all alarm on system parameters, safety issues and status of network elements.</td>
</tr>
<tr>
<td>Contingency analysis</td>
<td>To carry out detailed analysis of system conditions like faults, overload, violation of network parameters or trippings etc.</td>
</tr>
<tr>
<td>Merit order dispatch</td>
<td>To develop generation dispatch schedules of various generating stations based on cost of generation such that the cheapest generation is dispatched first.</td>
</tr>
<tr>
<td>Monitor data transfers</td>
<td>To monitor that all the EMS applications are running in order and the data transfers across all communication channels in the network are active.</td>
</tr>
<tr>
<td>Dispatch simulation training</td>
<td>To train operators on system operation with simulated situations picked up from real-time incidents.</td>
</tr>
<tr>
<td>Electricity market</td>
<td>In an electricity market, EMS facilitates all scheduling and power trade in an optimal manner across all the constituents of the market based on constituent requisition.</td>
</tr>
</tbody>
</table>
EMS APPLICATIONS

The applications in an EMS may be segregated into two categories. The main or primary applications are typically SCADA, Automatic Generation Control (AGC), and alarmings. All other applications are categorized as subsidiary or child applications.

The primary applications provide the necessary information for the child applications to function. Hence, if the primary applications have defective or missing data over a certain threshold, the child applications will provide erroneous output when they are run and the solutions may not converge thereby giving erratic values. The child applications take raw data from the three primary applications as inputs and process it using other data such as the system model, which include topology maps, impedances, and alarm settings to provide the outputs.

The following table provides an overview of the various applications and systems typically found in an EMS and the functionalities they provide to the system operator. Note that different vendors may offer slightly different applications with proprietary names.

In summary, the primary applications of SCADA, AGC, and Alarming are the minimum requirements to operate the grid. All child applications enhance efficiencies, mitigate contingencies, and perform minor adjustments to the primary applications.

Table 2: EMS Applications

<table>
<thead>
<tr>
<th>Application/System</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Applications</strong></td>
<td></td>
</tr>
<tr>
<td>SCADA</td>
<td>To facilitate data transfer (values and status) between the generating stations, the transmission network and the distribution network equipment to and from the EMS. This is achieved by installing Remote Terminal Units (RTUs), which are communication equipment, at each station and also in the control center. The raw data collected in the field is transferred by the RTU to the control center and vice versa. In the control center, the raw data gets converted to a meaningful measure and for use in the database or displays.</td>
</tr>
<tr>
<td>Generation control via AGC</td>
<td>To remotely match the total generation in a power system with the variations in the demand so as to obtain a load generation balance.</td>
</tr>
<tr>
<td>System Alarming and Logging – Analog and Status</td>
<td>This application highlights all variations of data from the limits and also provides status updates in a time stamped sequence. This also includes station abnormalities such as fire, security, and other primary and secondary station alarms. For example, voltage crossing permissible limits, opening or closing of a circuit breaker, winding temperature of a coil going beyond limit, a transformer tap setting changed remotely by the operator, fire on an equipment in the switchyard etc. Similarly, when the normalcy is restored, an alarm is set off automatically to indicate the same.</td>
</tr>
<tr>
<td><strong>Child Applications</strong></td>
<td></td>
</tr>
<tr>
<td>Communications Alarming</td>
<td>This alarm provides status updates on availability and healthiness of the various communication channels like fiber, Power Line Carrier Communication (PLCC), Microwaves, Radio etc. which are used across the network to transfer data from</td>
</tr>
<tr>
<td>Application/System</td>
<td>Purpose</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------</td>
</tr>
<tr>
<td>one point to another. For example, if the PLCC link between Benin and Oshogbo is down, the alarm will show on the EMS that it is not functioning.</td>
<td></td>
</tr>
<tr>
<td>Generation Scheduling and Optimization</td>
<td>Using real-time model results, load forecasts recommend the course of action for operators to optimize generation both for reliability and economics.</td>
</tr>
<tr>
<td>Critical to many other applications, it takes SCADA data and runs real-time reiterations to estimate the ideal true status of the current grid (resultant output should be more exact than SCADA data or Power System Simulator for Engineering (PSSE)). Data can be substituted in some cases for failed RTUs.</td>
<td></td>
</tr>
<tr>
<td>Contingency Analysis</td>
<td>Using state estimation data, it tests all critical contingencies, displays likely outcome, and offers steps to mitigate if possible, the contingency, such as changing generation or equipment status. Pro-active operation as opposed to reactive.</td>
</tr>
<tr>
<td>Short Circuit Analysis</td>
<td>Using state estimation, it calculates short circuit values and alarms on potential violations. Violations could cause catastrophic equipment failures.</td>
</tr>
<tr>
<td>Optimal Power Flow Analysis</td>
<td>Using state estimation it offers configuration changes that will result in more economic operation ultimately reducing system losses.</td>
</tr>
<tr>
<td>Manual Triggered Computer Assisted Load Shedding Control</td>
<td>When manual load shed is required, provides a method for non-discriminatory load shed equal to the MW required (discrimination can be built in if required). Allows for fair and semi-automatic rotation of manual shed load.</td>
</tr>
<tr>
<td>Load Forecasting</td>
<td>After building a database of historical load and using forecast weather and cultural coefficient, forecasts loads for next 15 minutes, next hour, next day, and for the next week. This forecast is then used to schedule generation and pre-plan outages in a reliable and economical manner.</td>
</tr>
<tr>
<td>Energy and Transmission Constrained Dispatch and Economic Dispatch</td>
<td>Using state estimator data, load forecasts, costs, and grid capability limits, advises on the best set points and unit schedules to optimize generation and transmission respecting security limits.</td>
</tr>
<tr>
<td>Volt-Var Dispatch</td>
<td>Using state estimator data suggests (or controls if trusted) voltage and VAR set points for economic operation and security.</td>
</tr>
<tr>
<td>Reserve Calculations and Allocations.</td>
<td>Using state estimated value and equipment ratings displays reserves for both generation and voltage control by area.</td>
</tr>
<tr>
<td>Dispatcher Training Simulator (DTS)</td>
<td>Using the model in state estimator, recorded actual configurations and recorded events allows trainers to simulate the grid and dispatchers to practice system operation and see the effects of their actions in a safe training environment. New equipment may also be simulated before placing online. All applications in EMS are also able to be simulated. The concept is like a flight simulator for pilots.</td>
</tr>
<tr>
<td>SCADA – Logging, Alarming, Recording and Historical Replay</td>
<td>Allows recording of all events to historians for analysis and retrieval. Recorded events can be played back like a movie for the benefit of training and understanding.</td>
</tr>
<tr>
<td>Application/System</td>
<td>Purpose</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Renewable Energy Capacity Forecasting</td>
<td>Applications forecasting wind and solar availability based on wind, opacity, temperature, and historical generation.</td>
</tr>
<tr>
<td>Hydraulic and Fuel Optimization (Optional)</td>
<td>Using state estimation, costs, and must run information, offers generation reconfiguration to save fuel and water (hydro plant energy) and run in the most efficient manner respecting water levels and flow licenses including run of the river generation.</td>
</tr>
<tr>
<td>Auto Sequence Switching Control (Optional)</td>
<td>If used, it performs complex switching sequences in a quick error proof manner.</td>
</tr>
<tr>
<td>Miscellaneous Applications</td>
<td>Unique applications based on local grid requirements that allow for meeting unique requirements of system operators, corporate and stakeholders needs. This can include HVDC, phase shifting transformer control, advisory, smart grid, mitigation programs, etc. If an application need is specified and can be solved using either SCADA, state estimation or external grid data, it can be created.</td>
</tr>
</tbody>
</table>

As mentioned, the first three applications being the primary applications are most critical and are covered in greater detail. All three are dependent on components external to the control center, EMS software, and hardware. The ability of all the EMS applications requires the first three to perform with a high degree of accuracy and reliability. The first three applications performing properly with proper EMS hardware/software will ensure the functionality of all applications if the electrical characteristics of the grid are modeled correctly. The bulk of data flows from the SCADA, AGC, and alarming systems to all other applications. Some data does however flow back to AGC and alarmings from some applications.

**SCADA**

SCADA is the information and control link between the field equipment and the EMS. The EMS continuously requires a huge volume of real-time and historical data from all stations, generation, transmission and distribution. This data is used by the various programs to arrive at feasible solutions to optimize the operations. This data collection, storage, and two-way communication between the control centers and other stations is handled through an effective SCADA and intertwined communication system. The communication system continuously transmits signals (data) from the field to the control center for analysis and on a return path carries the implementation signals back to the field like opening and closing circuit breakers, adjusting tap changers on transformers, opening and closing motorized switches, adjusting generation in response to AGC, and any control functions that should be controlled remotely. The SCADA also provides feedback on the status of breakers, switches, and other discrete devices as well as the actual analog values of network parameters such as voltage, current, frequency, and active/reactive load. The inputs received are also used to create simulations of the real situations for use by the child applications.

The main system components and requirements for the EMS/SCADA are detailed in the section below with a full diagram under Figure 1: Typical Components of EMS/SCADA.

**GENERATION CONTROL VIA AGC**

Every generating station on the network can be controlled locally or remotely. AGC is a primary application in the EMS to control the generation remotely. For any power system, the demand changes...
continuously. The AGC application notes this change of demand and calculates the change of generation required, this volume of change of generation necessary is calculated by the Area Control Error (ACE) formula. Following this, the AGC application sends inputs to the generating station to regulate the generation so that the generation and demand is balanced at all times. This entire operation is completed and signals are typically sent on an eight second cycle. While it may seem simple considering one generating station in the system, the application carries out a very complex operation as it remotely coordinates with all the generating stations in the network and regulates the generation output based on various factors like least cost of production, network security, and transmission line limitations. The mode of control of the AGC application is typically determined by the quantum of data and controls the application has access to, and the desired levels of accuracy to be achieved by regulation. Typically, AGC has three different modes of operation:

1. **Flat frequency control** looks at the current frequency and compares it with the desired frequency and calculates the ACE. ACE is the difference between scheduled and actual generation within a power-grid considering the variations of frequency. This value after some damping and other modifications for stability and economics, is sent to units on AGC control via the communication channels and the generation unit outputs are adjusted accordingly.

2. **Tie line control** looks at the current obligations on MW flows only and compares actual flows with the desired flows and calculates the ACE. After considering variations on the MW flows (eg. +/-1%) and other modifications for stability and economics, the value is transmitted to units on AGC control and the unit outputs are adjusted accordingly.

3. **Tie line bias control** is a combination of both of the above and looks at both the frequency and the flows against the desired and calculates the ACE, again with the appropriate modifications for stability and economics.

The AGC application considers parameters such as mechanical and electrical characteristics of the generating stations, their loads, metering errors, reserve requirements as per grid models based on the physical properties of the grid, regulating frequency, regulating interchange obligations, and economic control (based on other child applications) while adjusting generation.

The main benefit of the AGC application is that it achieves optimal dispatch of the available generation to meet the real-time demand, while considering the system constraints.

**SYSTEM ALARMING – ANALOG AND STATUS**

System alarming brings abnormal events to the attention of system operators. When any undesired, abnormal or dangerous condition occurs, the event is transmitted by SCADA to the alarm processing application and is displayed immediately to the system operator.

These events can include, for example, breakers tripping due to faults, analog values such as voltages being too high or low, equipment failures such as battery chargers failing, etc. The events are time stamped according to GPS clocks. When an event becomes normalized, the item is also reported in a similar way. This gives the system operators a high level of situational awareness and allows them to take the best course of action to address problems.

It is important that all equipment in the field is properly wired to the communications system to ensure that the System Alarming notifications are communicated to the EMS system on a real-time basis.

**SYSTEM COMPONENTS AND REQUIREMENTS FOR EMS/SCADA**

The main EMS/SCADA system components and resources required are:

1. **Station remote terminal units (RTUs) and station interposing relays, transducers, and associated wiring** - Ideally stations should have Human Machine Interface (HMI) and/or
Substation Automation System (SAS) equipment already installed and commissioned. Station control equipment mentioned here must be provided with Uninterruptible Power Supply (UPS) connections and properly cooled.

2. **Communications equipment** (redundancy is a normal requirement) - This includes but is not limited to utility owned fiber optics (preferred), power line carrier (PLC), microwave and possible dedicated guaranteed secure leased circuits.

3. **Front ends at control center** - These are dedicated servers, software, and hardware that obtain and do the preliminary sorting (typically by exception/change) of SCADA communications. They automatically connect to RTUs in the field and manage communications. They are also the firewalls between the communications data and the heart of the EMS. They forward the data to the main EMS servers. They also allow communications to travel to different types (different vendors) of RTUs. They allow all monitored points of the grid to be scanned typically every 4 seconds.

4. **EMS computers and development servers** - Redundancy is important and it is recommended that there be main and backup servers at the main site and at least one at the backup sites. These process the data, control actions, alarming, and most child applications for display to individual workstations and wall displays.

5. **Firewall servers to corporate and external users** - Inter-Control Center Communications Protocol (ICCP) links to other control centers. This is important to keep the EMS protected from computer-based viruses and possible hackers.

6. **Bumpless (Thyristor) uninterruptible power supplies (UPS) for all equipment and generating stations** - These provide the ability to perform maintenance to power supplies and ensure little or no chance of failure of the EMS due to regular power system disturbances.

7. **Main wall display(s)** – For overviews and situational awareness in the whole control room.

8. **All required software**

9. **Communications, hardware, software, maintenance and training support staff**

10. **Operator and software maintainers/developers’ workstations**

The EMS/SCADA system requires appropriate physical buildings properly located with the required infrastructure.

The following figure shows only general configuration from one point and one analog value (bottom left) in a substation to an operator workstation (top left), without auxiliaries and supporting hardware. Different vendors will have different details and configurations.

This drawing does not include a redundant control center, developer and maintainer servers, or dispatcher training simulator equipment.
In Figure 1, the assumption is made that a PLC and HMI or Substation Automation System (SAS) previously exists. In the case of older stations, a significant amount of work will be required to provide this interface point to the RTU. This could include creating “as built” wiring diagrams and even having to purchase new devices such as potential banks, current transformers, and in the extreme case new circuit breakers. Depending on the current status of the stations, this could entail a very significant increase in engineering effort and cost in installing an RTU. Any new stations being constructed should have an HMI interface available as it is a normal requirement. Most new stations will also have SAS equipment as part of the station equipment.

If an RTU existed previously with communication channels, any qualified vendor will have the interface and software to communicate with it. It is not a requirement for original vendors to interface with legacy RTUs. In many cases due to age of previous equipment, new RTUs will be required due to lack of replacement parts and other obsolescent issues including not conforming with current industry standards such as ICCP and IEC communications protocols.

IMPACT OF A FUNCTIONING EMS

The growth of the electrical industry bulk grid in Nigeria requires a system operator to have the necessary tools which include a fully functioning EMS. This is required for both reliability and economics. Central
control also facilitates safe operation by making equipment safe for tasks, for example de-energizing transmission lines for maintenance and repairs.

Reliability will also increase dramatically as information will not have to go through a verbal chain of command, as it does today.

ALARMING AND CONTINGENCIES

A fully functional EMS with alarming and contingency analysis and other child applications will allow operators to stop many disturbances and shutdowns before they can develop. This is one of the main differences between an EMS and a simple SCADA system. Problems and potential problems are identified before they escalate to major disturbances or equipment damage.

DISTURBANCES AND RESPONSE

When a disturbance does happen, restoration will be sped up because operators may take direct action by control and also have direct knowledge of the conditions being dealt with as well as quick confirmation of the effect of their actions during restoration. The control component of SCADA in the EMS allows corrective actions to be taken quickly and with observance to the ‘big picture.’ The EMS points to the most critical actions to be addressed first.

ROUTINE SWITCHING AND STAFF UTILIZATION

With a functioning EMS, all control functions and switchings will be carried out remotely from the control center, resulting in field staff being utilized more efficiently. In Nigeria, all switching operations are carried out locally by the field staff. This means that staff must be physically present in each station to carry out switching operations and report all locally generated alarms verbally to the control centers.

All control functions desired by the control center must be verbally given to the field staff creating delays in action, along with the potential for incorrect verbal communication. There is little time or opportunity to perform other worthwhile tasks including analyzing situations for reliability or economics.

A functional EMS will free up time for field staff to perform maintenance and inspections. TCN employees will see more value from their work as many tedious tasks will be automated. Staff will become more challenged, skilled, and valuable.

The net result is typically a better trained and valued staff performing at increased productivity and reliability levels. These human resource changes will be applied over many years and should not make staff feel threatened with redundancy. Instead, these changes should be seen as an opportunity for advancement as many new staff will be required to maintain, commission, plan, and program the EMS.

ECONOMIC EFFICIENCIES

In addition to system improvements for control and monitoring of equipment, a modern EMS will result in greater economic efficiencies including:

1. Reliability based economic dispatch, matching the cheapest generation to the load while respecting reliability, and helping to meet deregulation ultimate goals.

2. Allow interconnections with other countries within the West Africa Power Pool or control areas using AGC for energy transactions and billing without being limited to current radial loads.

3. Spinning reserve ‘sharing pools’ will be possible allowing for both increased reliability and cheaper aggregate prices of carrying spinning reserves across countries and control areas (the cheapest spinning reserves will be utilized based on cost and available transmission capability). These shared resources will reduce costs of reserves and create economic benefits to all stakeholders across the value chain.
4. Improved outage planning, approvals, and tracking which creates resource awareness.

5. Smoother energy scheduling (five minute and hour ahead market possibilities) both by suppliers and users to increase commerce (some billing functions can be included). Opportunities for real-time markets can be created.

6. Proper allocation of losses and their costs and reduction of losses using optimization applications.

7. Transfer of accurate economic and system data to outside of control room stakeholders and decision makers in TCN including the regulator amongst others. They will better monitor, utilize, and plan energy resources with less uncertainty.

8. Proper billing for energy and proof of grid compliant delivery. Market participants will be monitored to ensure contractual obligations are met.

9. Improved interface with distribution companies through EMS data and smart grid data for increased efficiencies such as time of day billing and accounting for surplus or back feed energy.

10. Load forecasting, near real-time, hour ahead, day ahead, and week ahead (longer forecasting is typically done external to the EMS but still relies on historic EMS data). This helps ensure adequacy of scheduled energy resources. Starting and stopping generation units in an economic and reliability focused fashion requires good load forecasting. This is also a critical element for integrating renewable energy, such as wind and solar generation effectively into a grid.

**Load Forecasting** – The EMS performs load forecasting on various time horizons using near real time data and historical data. Typical time horizons are 15 minutes, 1 hour, 24 hours, weekly, and in some cases yearly. Forecasts over longer periods use the EMS historical data. These forecasts include co-efficient such as opacity, wind, wind direction, humidity, temperature, known social and religious events, entered schedules, and all near real time EMS data. Good load forecasting is critical to economic and planning activities.

**SAFETY**

Centralized authority for “clearing” (switching out and making safe) equipment, switching errors or missed communications that put field staff at risk will be minimized with a functioning EMS.

The EMS will allow all possible points of energization to be monitored and ensure equipment is properly removed from service prior to releasing equipment for field staff to work on. The switching sequence or program to make equipment safe can be administered from one office (control room) overseeing the whole process from start to finish while ensuring all steps are executed in the correct sequence. Safer switching also improves reliability by reducing equipment tripping during switching. This is especially true when dealing with transmission lines which span stations and large geographical areas.

Fault currents will be calculated by a child application in the EMS. This will guide system operators to keep these values below the rating of the installed equipment. Failure to perform switching steps or to keep available fault currents below ratings can result in catastrophic failures of equipment.
HISTORY

HISTORY OF EMS/SCADA IN NIGERIA

The EMS/SCADA history of TCN dates to 1988 when TCN (formerly Nigeria Electricity Power Authority (NEPA)) obtained the DASA system from ABB Limited with only one master station. It was commissioned from the National Control Center (NCC) Oshogbo to cover 330KV stations and the NEPA generating stations. This system was in service till 1995. In 1995, a Siemens Spectrum system was set up in the Supplementary National Control Center (SNCC) in Shiroro which is referred to as the SNCC SCADA. It also covered 330KV stations and NEPA generating stations. It was mirrored to NCC Oshogbo so that in case of any eventuality at SNCC Shiroro the system could be run from the NCC.

In 1992, a pilot project was executed to have the 132KV stations of the Area Control Center Shiroro, under SNCC Shiroro connected via the Siemens Spectrum SCADA system.

In 2004, with funding from the World Bank, a new EMS/SCADA system called the Siemens Spectrum system was procured to cover all 132KV and 330KV stations and generating stations. This is referred to as the World Bank SCADA. The system was to be based in NCC Oshogbo. This project was meant to cover the entire country and there were stations where new electrical equipment were to be installed in the switchyards or substation control rooms so that data from each equipment could be picked up. The project was never fully commissioned under TCN who had to carry out the work of installation of equipment in various switchyards and wire due to various constraints. In 2010, Siemens abandoned the project having done what was possible as part of their contract. This left TCN dependent on the SNCC SCADA being run from NCC.

Since 2009, the SNCC SCADA system progressively started to lose station connectivity such that in early 2012, only four stations were transmitting data as against one hundred and eight connected stations. This emphasized the urgent need to revive the SCADA system procured from Siemens AG Germany with World Bank finance. A reactivation contract was executed with Siemens AG Germany as the lead contractor and Telemit International as the local telecom partner. The execution of this contract ran into various hurdles as the contract was not well drafted to capture all the tasks and there was further delay in processing the letter of credit in favor of Siemens.

It is worth mentioning that with SCADA providing such a limited coverage of data from the network, the EMS applications could not be fully commissioned and the child applications of SCADA, AGC, and alarming were nonfunctional.

Until 2014, there were no telemetry standards for communication between various equipment in generation and transmission which hindered seamless data transfer to the National Control Center. Presently, a broken-down version of World Bank SCADA is available for TCN to monitor the grid, which is the reason behind the manual operations, low visibility of the network, and non-operative applications.

In 2015, the SCADA covered approximately 50 percent of the generation and transmission system in Nigeria. Due to a lack of spare parts and maintenance, this percentage has gone down considerably in the last five years to less than 14 percent.

The NCC was built to house the World Bank SCADA but was not completed as can be seen in Figure 2 below with unpaved roads, lack of a boundary, wall and signage.
The Main Control Room is not adequately lit and the staff have a cramped seating arrangement which is not up to standard and creates a poor work environment.
CURRENT STATE

CONTROL CENTERS

TCN has two control centers in Nigeria, the National Control Center (NCC) in Oshogbo and a backup center referred to as the Supplementary National Control Center (SNCC) in Shiroro. There are two regional control centers; one in Benin and the other in Ikeja with eight area control centers throughout Nigeria. All substations are manned 24/7 to perform the switching tasks and system monitoring which would otherwise be executed via the EMS/SCADA system.

SNCC is over 450km from NCC Oshogbo and if there is a need to transfer control from NCC to SNCC it requires physical intervention by local staff from SNCC to perform the operation in an orderly manner, leaving room for excessive delays and error. This is not optimal by any standard.

NCC Oshogbo is physically located next to a major substation and 330KV lines. This is visible on google maps, thus violating normal siting standards. This is of concern because if there is a fire at the switchyard or if a conductor snaps in the overhead line, this could cause damage to the NCC which would affect the entire operations of the Nigerian grid. The high voltage on the 330kV lines has an adverse effect on the communications equipment in the NCC.

EMS/SCADA

As of the writing of this report, a functional EMS/SCADA per international standards does not exist in Nigeria.

The above statement is supported by several sources, including by Électricité de France (EDF) engineering consultancy reports recently commissioned by TCN, daily reports, and meetings with TCN SCADA and communications engineers.

According to six daily reports of TCN (21 June through 26 June 2019) and looking at existing and suggested plans (EDF Report), the following table shows the count of RTUs which are required in the network against the ones which are functional and exchanging data with the EMS. None of the RTUs installed at generating stations have Load Frequency Control (LFC) or Automatic Generation Control (AGC).

Table 3 is a summary of TCN’s total required, total installed, and total functional RTU’s. The data shows that the total functional RTUs are 15 percent of the total requirement in 2017 and that only 29 percent of the total installed RTUs are functional which is extremely poor.

Table 3: Summary of TCN’s RTU Requirements

<table>
<thead>
<tr>
<th>Type of Station</th>
<th>RTU Based</th>
<th>SAS Based</th>
<th>Without RTU</th>
<th>Under Construction</th>
<th>Total Required</th>
<th>Total installed</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>330kV</td>
<td>15</td>
<td>11</td>
<td>1</td>
<td>3</td>
<td>60</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>330/132kV</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>4</td>
<td>60</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>330/132/33kV</td>
<td>4</td>
<td>7</td>
<td>-</td>
<td>2</td>
<td>172</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>132kV</td>
<td>9</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>172</td>
<td>21</td>
<td>21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Station</th>
<th>RTU Based</th>
<th>SAS Based</th>
<th>Without RTU</th>
<th>Under Construction</th>
<th>Total Required</th>
<th>Total installed</th>
<th>Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>132/66/33kV</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>132/33kV</td>
<td>82</td>
<td>20</td>
<td>21</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33kV</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generation to 330kV</td>
<td>7</td>
<td>-</td>
<td>14</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generation to 132kV</td>
<td>1</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>29</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Generation to 33kV</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td>122</td>
<td>47</td>
<td>45</td>
<td>43</td>
<td>261</td>
<td>129</td>
<td>38</td>
</tr>
</tbody>
</table>

### Functional/Total Installed (%)

| Functional/Total Installed (%) | 29% |

### Functional/Total Required (%)

| Functional/Total Required (%) | 15% |

Source: Composite table of EDF report and TCN daily reports

If the RTUs are not functioning, this means that there is no data exchange with NCC. For an EMS to function properly at NCC, all stations must have functional RTUs. Maintenance of the RTUs is required to keep them at a functional state to facilitate data exchange between the particular station and NCC. Maintenance may require spare parts which are inexpensive, a full replacement of an RTU is however expensive. An RTU has two functions:

1. To transmit data and statuses from the field to the EMS which is referred to as reporting.
2. To transmit signals from the EMS to the equipment for operations, which is referred to as supervisory control. Of the 38 functional RTUs at TCN, none have supervisory control, only reporting capabilities. Without supervisory control the equipment cannot be remotely operated. Reporting capabilities only allow viewing of data and the status of the equipment.

The TCN Grid map in Figure 3 below shows the existing and future network in Nigeria, highlighting the requirement for RTUs. In 2019, TCN SCADA engineers estimated that the total requirement for RTUs is over 277 over the next three years.

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4 Information from TCN SCADA and Communications Engineers meeting discussions - November 15, 2019 held at the PA-NPSP office in Abuja
Without robust SCADA data elements, AGC control, and a meaningful alarming system, there are no elements that resemble a functioning EMS at TCN in Nigeria.

All child applications of SCADA, AGC, and alarming are not possible, even if the software was purchased.

If all the previous equipment installed were functional there would still not be enough RTUs, communications, or station equipment in service to have a proper EMS based on current and expected station counts, which are listed at over 277.

The UPS in the control centers are nonfunctional and there is a high dependency on diesel generator sets and makeshift UPS of lower capacity, which are typically for individual use. An industrial sized UPS and backup UPS are required for substantial protection. As a result, during power interruptions it is common for the entire computer system to restart, interrupting the available EMS applications which is far from an ideal operation. In a functioning system, the EMS should be on an uninterrupted power supply 24/7.

In December 2017, independent EDF consultants were able to visit most of the TCN stations and reported on their deficiencies.

To summarize their findings:

- Of the 24 - 330kV stations designated “RTU” capable that were visited, in eight stations, the RTUs were either damaged or not wired.
- Of 113 - 132kV stations designated “RTU” that were visited, only fifteen were visible to SCADA, all others were either burnt up, defective, or never installed.
• Also of 47 SAS stations - both 330 and 132kV that were visited, only four had RTUs with the other 43 having the potential to be connected. It is possible for these stations to be connected at a relatively low cost if the communications and interface equipment have been installed correctly and are functioning.

• Of 29 generation stations visited, six had the necessary interface for generation control, but none were wired-in or connected to any RTUs

• 42 stations were under construction at various voltage levels (330/132/66/33 kV), but only five had automation equipment as part of the station design. There was no provision for SAS, RTU, or RTU/SAS/communication on these sites.

• 33 stations at various voltage levels (330/132/66/33 kV) have no RTU or SAS installed or they are defective.

COMMUNICATION INFRASTRUCTURE

For SCADA and AGC to function, communication is vital. Very large bandwidths of data must flow in a secure fashion with preferably redundant paths. Communications uses mainly fiber optics, Power Line Carrier Communication (PLCC), microwave traffic, or dedicated hard wired (twisted pair multiplex) and sometimes dedicated leased circuits can be used.

In most utilities, fiber optic cable, PLCC, and microwave are the preferred methods with Fiber Optic Cable being the most desirable due to reliability and bandwidth. The Party Line System (PLS) is only used for voice communication across stations and is therefore less desirable as it does not carry data.

The table below has been compiled from data of TCN Daily Operational Report dated February 21, 2020 in voice and data transmission. Of the two most desirable methods of communication structure, only 50 percent of the PLCC’s and 69 percent of the fiber optic cable are active which means there are limited channels for transfer of data.

Table 4: TCN Fiber Optic System

<table>
<thead>
<tr>
<th>Communication Channel</th>
<th>Installed (No.)</th>
<th>Active (No.)</th>
<th>Percent Active (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLCC</td>
<td>38</td>
<td>19</td>
<td>50%</td>
</tr>
<tr>
<td>Fiber Optic Cable</td>
<td>13</td>
<td>9</td>
<td>69%</td>
</tr>
<tr>
<td>PLS</td>
<td>14</td>
<td>4</td>
<td>29%</td>
</tr>
</tbody>
</table>

The status of the fiber optic network at TCN is far from adequate. Most of the 1380km of the existing fiber optic cables on TCN right of ways is controlled by two external companies who have the rights to the bandwidth and are designated as the service providers.

According to industry standards, TCN should own and control all of their fiber optic network as they are the only ones who will have the incentive to maintain and expand the network.

The contract allowed the concessionaires to have full control over the network and TCN’s access was limited. All future additions to the fiber optic network were also to be part of the same agreement thereby making TCN completely reliant on the concessionaires. The concessionaires maintain the fiber only for the portion where they have traffic, thus TCN data flow has suffered. Under the contract, the concessionaires were required to lay new 24 core fiber, but these conditions were not followed resulting in lessor cores or no fiber at all as no traffic was envisioned. The contract does not address how to rectify these issues.
Though exceptions exist, in most electrical utilities the communications infrastructure is typically owned and run by the utility which includes all fiber optics. When utilities do buy these services, they have priority over all other traffic. In Nigeria the power system does not control or have priority on the fiber that runs in their own right of ways.

In North America, when an outside service provider may occasionally have the fiber franchise, the utility has both exclusive use of the bandwidth and highest priority. If the path is severed it will be placed back in service by bumping any other traffic immediately if not automatically. Routine maintenance by either a provider or the utility should not interrupt traffic without re-routing, and routine maintenance should take place after very careful planning.

The entire power system from generation, transmission, and distribution, was owned by the government of Nigeria prior to privatization. During this period, the SCADA infrastructure was either poor or nonexistent. Privatization has not created any incentive (by observation of results) to improve the situation as all successor organizations, NIPPs, IPPs, GENCOS, and DISCOS have not seen SCADA as a priority because of the high costs involved.

A report by consultants from Manitoba Hydro International (MHI) (2012/13)\(^5\) identified that no cohesive strategy for a telecommunications department existed. This has not changed based on current RTU and communications performance.

All plans in the past have been at a high level without disseminated functional plans at lower levels. The plans were mostly discussed and finalized at the management level without taking inputs of the operation teams and field staff, which resulted in the plans not being implemented due to fundamental issues, including right-of-way and material availability. The two companies that had the franchise to provide, run, and maintain the fiber on behalf of TCN in evidence of the current state of the communication network have failed to deliver. At the time of this report, TCN is in court attempting to regain control of the fiber network from these two companies.

Also noted by the Management Contractor appointed by the Government of Nigeria to run TCN from 2012 – 2016, was a failure by TCN, Generation, and Distribution entities to coordinate efforts on telemetered data. According to the Nigerian Grid Code, and found in other countries grid codes and rules and by industry standards, telemetered data must flow freely between power system entities. This is not happening in Nigeria due to failures in the communication network.

The current fiber is not being properly maintained, recent daily reports from June 2019 show that of the 13 links installed, 2 were out of service for multiple days.

Any EMS project must have good, redundant communications built in parallel with RTU additions. No link should be out of service for more than one day except in cases of catastrophic failure. This is important not only for SCADA data but also for system reliability on protective relaying of inter-site telemetry necessary for fast clearing of faulted equipment.

Communications systems are critical to other aspects of system operation. A secondary critical role apart from SCADA for communications channels is for protection of transmission lines (for example, pilot wire permissive tripping relaying) to increase the reliability of transmission line operation, to help prevent disturbances from becoming total grid shutdowns.

\(^5\) MHI (management of TCN 2013) – Milestone 8 Report: SCADA, Communication Infrastructure and Operational Communications – Feb 7, 2013
TCN does not meet the Nigerian Grid Code⁶ requirements for existing or new communications facilities identified in Part 3 Section 4.3 (current version 13.3) – Telecommunication Installations. This is based on the current lack of SCADA and AGC availability.

Planning, design, and maintenance of operational communications systems are severely impaired due to the lack of control/coordination of projects being executed by National Integrated Power Projects (NIPP) and other independent power producers. This is further aggravated by the lack of standardization in the procurement of equipment by TCN, NIPP, and other power producers. Data should be freely transferred by the ICCP link across the constituents of the network and it should be possible to configure all the systems in the network.

The SCADA re-activation contract (for the Siemens SCADA supplied via a World Bank funding) which was carried out in 2013 had limited scope and was not able to revive the entire system. There are many other issues that must be attended to once SCADA is back in operation.

TCN SCADA and communications groups need to be reorganized, which is in line with the recommendations by the Management Contractor appointed by the Government of Nigeria to run TCN from 2012 – 2016. Both SCADA and communications groups should each have a department looking after all aspects (maintenance, operation, design, and planning) of their technologies. Evidence of current operation suggests little or no change has occurred, but if it has, they have been ineffective.

TCN SCADA and communications maintenance and design/planning groups are understaffed at the field level and lack centralized coordination and planning.

Major problems exist with the design, implementation, and maintenance of the DC and AC backup power supplies necessary to support SCADA and operational communications systems. This has been reported continually by several consultants and verified by the current evidence.

Training, tools, spare parts, and test facilities as well as preventative maintenance to SCADA and communications are inadequate. The current SCADA system comprising old technology does not have adequate access to readily available spare parts from Siemens as they are obsolete.

TCN lacks a centralized alarm/network management system for communication. It also lacks the expertise and processes required to analyze the information that is available and to ensure a proper response. Today, the bulk of the communications are controlled and virtually owned by other entities. The fact that no complete EMS exists confirms that no communication central control or monitoring exists.

The data which comes through the SCADA system is not time stamped so determining the sequence of events in case of disturbance is very difficult. Disturbance reports recently reviewed show this to still be the case as no timestamps that could be verified were included.

The current TCN fiber optic system shown in figure 5 below, indicates that there are no noticeable loops of the fiber optic network. Loops are a prerequisite if the required reliability is to be achieved as it provides an alternate path for data flow to avoid loss of any station telemetry and control.

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In summary, the poor maintenance by the current fiber optic franchise holders, lack of a reliable TCN owned and controlled redundant bandwidth, lack of connected nodes and redundant loops means that an adequate SCADA is not possible using the current fiber installations or management thereof.

In addition, current telecommunications staff are not prepared to perform the necessary maintenance due to lack of resources such as skilled staff, test equipment, ongoing training, procedures, and coordination with other entities including GENCOs and DISCOs. Spare replacements are also lacking or obsolete. The evidence for this is the current state of availability of the communications circuits.

**SUBSTATION CONTROL AND MONITORING (RTU)**

Today a limited number of RTUs at substations are functional, by recent report 35 out of 121 previous installations are functional. These failures are not broken down by cause, though the reasons will be a mix of Station/RTU failures and communications failures. In addition, over 115 additional substations are either required or will be required based on estimates of the grid expansion and other consultants' reports.

**GENERATION CONTROL AND MONITORING**

No power generating station is currently on AGC control in Nigeria as only three generating stations have functional RTUs but none of them are commissioned to control the generation. The remaining five RTUs are all faulty which means there is no data exchange from these generating stations with the EMS. All faulty RTUs must be replaced or rectified.

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7 Multiple TCN Daily Reports dated June 21 – 26, 2019
SOFTWARE IMPLEMENTATION (PACKAGES AND MODULES)
No software implementation of advanced power applications is possible because of a lack of reliable SCADA data. No model of the power system has been placed in any state estimator application. None of the applications listed under EMS are functional.

GOVERNANCE AND REGULATORY FRAMEWORK
Section 12 and 20 of the Nigerian Grid Code lays out the requirements for communications and data. Section 20 calls for RTUs at all generation points and offtake sites (point of delivery to DISCOs).

The Grid Code correctly lays out the requirements for a functioning EMS even though it does specifically refer to one, other than referring to SCADA. The Grid Code Section 20.15.2 lays out that the standard for SCADA data should conform to International Electrotechnical Commission (IEC) standards.

None of these requirements have been catered to in the present system, hence there is only partial visibility of the system and no control. The new system will have to be compliant with the Nigerian Grid Code.

HUMAN CAPACITY
Procuring a working EMS will require using experienced staff for creating enough communications, recommissioning existing equipment, adding required RTU installations, control center(s) site selection, design and construction, EMS specification, RFP preparation, EMS vendor selection, EMS commissioning, training, and hand over to TCN. This will create an enormous requirement for experienced human resources.

TCN has neither the resources in trained staff nor experience to develop the expertise based on the results of previous efforts. Other critical entities including GENCOs and DISCOs do not have the expertise either. No framework exists for these three entities to work together to support grid code requirements which are necessary for successful implementation of a functional EMS/SCADA system.
DESIRED STATE OF EMS/SCADA

MODERN CONTROL CENTERS

TCN requires new control centers, built from the ground up, as opposed to upgrading current control centers as it will minimize disruptions to current operations. The present NCC location in Oshogbo has already been identified as unsafe due to its proximity to overhead transmission lines, a 330KV station, and other security concerns.

In order to cater to future requirements, the control centers should be built with the option to easily ramp up both square footage and capabilities in terms of servers, personnel, power requirements, and unknown future technologies.

The new control centers desirably should:

- Meet all security concerns including location(s).
- Have ample access to communication hubs, or have the hubs brought to them.
- Have proper task lighting and ergonomics for all operators.
- Incorporate feedback from system operators during design phase from actual operators, who have a strong understanding of actual needs.
- Have access to uninterrupted stable power supply as otherwise the UPS installed are subject to frequent failure.
- Should be within thirty minutes to one-hour travel distance from the Emergency Control Center.
- Should not be subjected to fires, floods, or any hazards.

EMS/SCADA

The desired state of the EMS in Nigeria requires that all the applications are in place and working. The necessary SCADA data, proper modeling, proper displays, and software/hardware to control and optimize operation of the Nigerian grid should be available as per the Grid Code. The EMS system must also provide the tools for system operator training and continued EMS development and expansion including coverage for renewable generation, and new elements as they are added to the grid. A functioning EMS should provide the tools required for system operations to be reliable, economic, and safe with adequately trained staff. Further, more than a simple SCADA, an EMS should provide operators greater situational awareness, control, and the ability to act proactively to possible events as opposed to reacting to events. The EMS should have the facility to include new stations.

COMMUNICATION

The desired state of communication should ensure that all stations i.e. generating stations, transmission substations at 330KV and 132KV are provided with fiber communication with a main and backup channel. Fiber loops with adequate bandwidth should be set up so that there is an alternate path for voice and data transfer. In stations where fiber connection is not possible, there should be dependable alternate modes of communication in a main and backup configuration, like microwave, PLCC, and radio etc. for both voice and data.

The communication facilities should be extended to all the control centers besides the NCC to facilitate seamless exchange of voice and data and the infrastructure should allow for expansion so as to include new stations as and when they are commissioned.

The telemetry standards should be adopted by all stakeholders and implemented so that all systems follow the same protocol for data transfer. This telemetry standard should be strictly enforced such that any
new station coming up in the generation, transmission, and distribution abides by it to ensure data and voice exchange with the control centers as per the protocol.

At present, the Nigerian Grid Code stipulates the requirements of an EMS/SCADA and communication system. The desired state is total compliance with this Grid Code stipulations.
RECOMMENDATIONS

The EMS/SCADA and communication system at TCN is technologically obsolete and plagued with operational challenges due to limited coverage. This justifies the necessity to procure a modern system in totality. While scoping and executing a new EMS/SCADA project, a couple of items need to be considered:

- The Inception Report by EDF entitled “Consultancy Services for Engagement of SCADA and Telecommunication” for TCN should be used for reference. Though the report was produced in August 2017, it highlights the discrepancies of the present system and details the requirement of a new system. The report is comprehensive as the consultants had an opportunity to embark on site visits to the control centers and substations and collected data from the sites directly.

- In TCN, the responsibility for execution of such projects is with a PMO. This being a specialty project, the PMO team handling these projects should be a pool of talents with requisite experience in procurement, EMS/SCADA and communication, project management, capacity building etc. so that all aspects are well taken care of while preparing the bidding documents.

- From previous experience of repeated attempts, it is evident that TCN lacks the capability to do a comprehensive scoping and successful project management of a project of such complexity. As is the best practice for such major projects, an Owner’s Engineer with requisite experience, should be appointed to assist the TCN PMO to scope the project and ensure successful implementation in its entirety.

- Though it is evident that the present EMS/SCADA and communication system is of obsolete technology there are lots of equipment which can be salvaged and reused based on compatibility with the new system. This should be considered as it will reduce project costs and speed up project execution.

- As seen in previous projects, TCN staff are unable to effectively maintain the EMS/SCADA and communication system. Based on those learnings, the new project should include a sizeable component for capacity building of TCN staff so that they can maintain the system regularly on their own. This will ensure that day to day issues are handled by the TCN staff directly while major problems can be covered by an annual maintenance contract with the main contractor.

- Modern technology requires frequent upgrades and most technology companies have issues providing spares for older projects. TCN financials are not healthy and procuring spares on their own or even opting for an entirely new system may not be possible. Future procurements should include sufficient spares so that equipment maintenance is not hampered due to paucity of spares.

- Lastly, in previous projects it was noted that the EMS/SCADA and communication project was awarded in parts to various contractors. This led to coordination issues amongst contractors and ultimately TCN bore the brunt of an incomplete system. To rule this out, while there can be specialist contractors for EMS/SCADA and communication, it should be in a consortium set up with a lead contractor so that ultimate responsibility of the entire work is with one entity.
Figure 6 – General Sequence of EMS/SCADA Development can serve as a guide for development and execution of the entire project. TCN requirements and inputs from stakeholders of the project such as generating stations, distribution companies, and West Africa Power Pool may necessitate changes.

Figure 6: General Sequence of EMS/SCADA Development

The EMS/SCADA and communication project of TCN, which has to be funded by the Federal Government of Nigeria (FGN) directly or via a development funding institution like the World Bank will ideally follow either the guidelines of Bureau of Public Procurement (BPP) under FGN or the procurement process of the development finance institution right from scoping the project to handover.

PMO AT TCN

Some of the steps that the PMO at TCN should consider vital are listed below.

ENGAGEMENT WITH EXTERNAL STAKEHOLDERS

As SCADA primarily affects the GENCOs and DISCOs, it is important that TCN’s PMO for this project engages regularly with these stakeholders. It is recommended that these stakeholders have an oversight of the project implementation by the PMO through a committee to review the progress throughout the design and implementation of the project. Feedback and information sharing from these stakeholders is paramount to ensuring a successful SCADA project.

Following implementation of the SCADA project, a human machine interface (HMI) terminal can be set up at both NERC and the Ministry of Power with access to view the system in real-time.
SITE SELECTION

Overview
In Nigeria, site selection for the new control center, both main and emergency, is important to the success of the project in meeting industry standards for successful operations and safety. If industry guidelines are not followed both security and reliability will be adversely affected.

Target State
The site selected must meet the criteria of being secure. This means the following should not be near the site:

1. Railroads or major highways with transport trucks.
2. Any electrical, chemical, petrol, or hazardous manufacturing or storage. (e.g. Google maps shows the present NCC to be near a switchyard and 330KV transmission lines).
3. Not subject to fires, floods, or likely insurrections, and can be easily defended.
4. Within thirty minutes to one-hour travel distance between sister sites.

The site(s) must be easily accessible to existing and planned communications paths and should be within commuting distance for skilled staff to live in a desirable area. The siting goal is to have it functional with scope for future expansion.

Actions
Site selection for the new main and emergency control center in Nigeria should be through a consultation process amongst the stakeholders of the control center and expert advice of the Owner's Engineer while adhering to the best practice guidelines.

VENDOR SELECTION

Overview
Vendor selection is critical for two aspects, the success of the project itself, and support beyond the project in terms of maintenance, spares, and capacity building. In the Nigerian context, this is very important because local vendors with necessary expertise to manufacture specialized equipment or execute specialized training on EMS/SCADA maintenance are hard to find and most international vendors do not have a base in Nigeria.

Target State
The goal is to procure cost-effective communication, RTU, EMS/SCADA, and control center(s). The Nigerian power system is expanding with new projects being commissioned on a regular basis. Hence it is very essential that the systems are scalable to accommodate new equipment and also rugged enough to handle the power situations and atmospheric conditions of the country. Nigeria is also an integral part of the West Africa Power Pool (WAPP) and the EMS systems for both power networks will need to be integrated for data exchange. This should be considered at the bidding and vendor selection phases.

Actions
The PMO should be guided by the Owner’s Engineer on the bidding criteria so that only reputable vendors who have extensive experience delivering successful projects of similar nature and provide extensive after project support are allowed to participate. The vendors should also be subject to competitive bidding to ensure the best products at the least price are obtained. All contractors and subcontractors should be chosen in a similar manner. This will go a long way to ensure a successful project with effective after project support.
RECOMMISSIONING EXISTING INFRASTRUCTURE

Overview

Considerable costs have been incurred in the past while trying to develop communication, RTU, and SCADA infrastructure in Nigeria. Major benefits and cost reduction can be achieved if the failed components from this existing infrastructure are salvaged and recommissioned as opposed to being scrapped and replaced entirely.

Target State

The old equipment, fiber, RTUs, and associated hardware at stations must be upgraded or repaired to a state that is compatible with new communication equipment and new EMS. Ensuring compatibility is not a major task for any reputable EMS vendor. As the elements are repaired prior to being used by the new EMS, basic SCADA functionality should be provided to existing control rooms to both provide interim value and ensure continued health of those systems.

Actions

The PMO should have an asset register of all the existing infrastructure and their conditions. This is the first critical step. A comprehensive list of equipment should be prepared with cost benefit analysis on the repairs needed. The interested vendors for the new project should be allowed to physically check the equipment as part of the pre-tender survey to avoid any ambiguity after bidding as they will be responsible for using these equipment’s in the new project.

COMMUNICATION EXPANSION SCOPE AND SEQUENCE

Overview

The fiber optic communication network will require upgrading and expanding to reach all the stations under the new EMS/SCADA and communication project. Once the project is completed, the fiber and all bandwidth should be owned by TCN.

There are two important items to be considered for the fiber optic communication system:

1. The new fiber optic layout should be configured in such a way that it provides alternate communication paths to all stations on the network. This calls for developing loops in the network.

2. The fiber network should allow for expansion to include new stations developed anywhere across the country or as required to communicate with the West Africa Power Pool.

Target State

1. Fiber must be expanded to entail all plausible generation station RTUs in conjunction with generation RTUs being made available.

2. Fiber must be expanded to include all distribution offtake sites (substation points of delivery) in conjunction with point of delivery (POD) station RTUs being made available.

3. Fiber must be expanded to include all 330kV stations, followed by all other networked substations and 132kV stations.

4. Fiber must be expanded to neighboring countries (for trade of energy and grid information) as well as into the DISCOs EMS systems. ICCP links for greater efficiencies of trade and reliability.

As part of the sequence to facilitate trade via WAPP, the point of delivery stations including metering and the generation RTUs/SAS control for AGC must be functional as well as ICCP communication to neighboring WAPP members.
The fiber expansion must include adequate training for TCN staff during installation and construction so they can effectively maintain the equipment.

**Actions**

The vendor responsible for the supply and layout of the fiber should also be responsible for the detailed engineering of the fiber optic network which should be verified by the Owner’s Engineer. This will be the responsibility of the vendor on a turnkey basis to limit discrepancy. In Nigeria, the practice of using different vendors to carry out detailed engineering, supply, and erections activities creates confusion which ultimately impacts the client negatively.

**RTU SEQUENCE**

**Overview**

Proper RTU sequencing will allow for quicker and sequential benefits to be seen by TCN and other stakeholders. It must also be coordinated with communications links becoming available.

**Target State**

The sequence should generally be as follows and dependent on the communication links being set up:

1. Generation station RTUs. Note that some of the RTU equipment may also provide local HMI capability that they did not have previously.
2. POD station RTUs (DISCO substations).
3. 330kV station RTUs followed by 132kV networked RTU (should include any terminal stations with other countries).

When step one is functional with communications and if generation units are available to AGC, then the units can be placed on AGC control (flat frequency control, if the EMS is installed in a new Control Center(s)). This should create better frequency regulation and economic dispatch possibilities.

When step two is completed, more accurate billing and load forecasting can start to occur with a new EMS along with limited SCADA control including EMS manual load shed capabilities.

When step three is completed and if the EMS model is accurate then all child applications plus required SCADA control for normal and emergencies can be employed (project effectively complete). Trade opportunities are possible if neighbors have enough infrastructure to network transmission.

**Actions**

The PMO must pick vendors, pick priorities, and perform the preliminary engineering in conjunction with communications deployment, TCN, GENCOS, and DISCOs. The vendors must train these stakeholders during construction on construction method and maintenance.

**EMS INSTALLATION**

**Overview**

The EMS is presently housed in the NCC at Oshogbo but the same is not fully mirrored in the SNCC Shiroro. Further, the EMS applications were not fully commissioned thereby providing limited functionality for TCN system operators to monitor and control the power grid on a real-time basis.

**Target State**

In all EMS systems, the hardware and software should be available in both the main control center and the emergency control center. The new project should ensure the same so that in case of any eventuality the operations carried out from the main control center can be shifted in full to the emergency control center.
This is the best practice globally. Furthermore, while commissioning the EMS it should be ensured that all applications are in full operations and there is data flow between all stations and the EMS.

Actions

The EMS installation is a major task in the entire project which requires careful monitoring by the client through the Owner’s Engineer. Further ancillaries like a stable power supply, a 24/7 UPS system, diesel generating stations in the case of Nigeria, and adequate flow of accurate data is to be ensured for effective commissioning of the EMS. At the project award stage these should be considered as an integrated approach, as absence of anyone could result in the EMS not being effectively commissioned. Further capacity building to run the application and troubleshoot problems in the EMS should be mandatory for all staff in all the control rooms. In the Nigerian context, with an aging workforce, there is potential for a gap in trained and experienced staff in the near future due to upcoming retirements. A succession strategy with training plans for new staff should be put in place.

AUXILIARY COMMUNICATION CONTROL CENTER

Overview

An Auxiliary Communication Control Center can be a standalone facility or be attached to one of the Control Centers. Its purpose is to control and support the integrity of the communications used by the EMS system and in some cases the corporate network. It controls the links between the RTU and the EMS as well as maintenance of the RTUs. It switches communications paths in and out, dealing with both maintenance and defective communications. They actively dispatch communications field staff for investigations and repair as well as commission new RTUs and communications circuits. In TCN, there is no auxiliary communication control center as all equipment are housed in the main control centers.

Target State

Wherever the Auxiliary Communications Control Center is located, it must have access to the status and control of communication circuits/switches and RTU statuses to front ends. It will require similar infrastructure to the control centers and so is often situated in the same building as the main control center, with limited fallback capability to perform emergency functions at the emergency control center.

Actions

The scope of the project should ensure that the Communications Control Center and the necessary equipment are part of the scope of the communications upgrades. During construction and commissioning, TCN communications staff must be trained in parallel with the establishment of the Communications Control Center.

GUIDELINES FOR MAINTENANCE AND TRAINING REQUIREMENTS

Overview

For sustainability, guidelines and standards for upgrade, expansion and maintenance procedures need to be created and handed over to TCN and other stakeholders. Training of the maintenance team is critical for success. During the first three to five years after completion of the project there should also be contracts for annual maintenance issued to the vendors which includes maintenance, supply of spares, and refresher training.

Target State

TCN must have the resources, (tools, spares, skilled staff, and funds) to maintain all elements that the project will hand over to them. Some DISCO and GENCO staff will also require similar resources.
**Actions**

The ongoing maintenance costs will have to be part of the System Operations tariff (to be determined). As the RTUs are installed, communications channels activated, and EMS commissioned, the TCN technicians, engineers, and software specialists should be trained in installation and maintenance. When the assets are handed over to TCN, the team at TCN should be in a position to operate, maintain, and add-on new stations. If this is carried out in a holistic manner it will reduce dependency on vendors for annual maintenance contracts, allowing the work to be completed internally in a more sustainable manner.

This will create requirements within TCN to establish system support departments, because the EMS/SCADA project will be used also by the generating stations and distribution companies and their staff will be required to maintain the terminal equipment at their end. These stakeholders should also be included in the system support activities and accordingly nominated for capacity building programs.

The scope of the project should include the capacity building programs and refresher courses for all identified staff-members and covering all installed equipment.

**HANDOVER**

**Overview**

Project handover on completion is an important activity of contract closing. In TCN it was noticed that there are no records of test reports, handover documents, site acceptance test reports, factory acceptance test reports, commissioning test reports, as well as built diagrams, and equipment brochures as they are either not available or are available in languages not understood by the appropriate engineers. In fact, the World Bank SCADA project is an example wherein there is no record of manuals, equipment spares etc. This is because it was not specified in the contract or the contract was not properly closed with a hand over process. This creates hurdles for the maintenance teams at site. It was also noticed that after the project was completed. TCN did not put an annual maintenance contract in place, thus leaving the project at risk from inadequate maintenance which led to equipment failures and unnecessary consumption of spares.

**Target State**

As the project is being commissioned, inventory of all equipment installed with all pertinent records and manuals should be prepared and transferred to TCN for proper record keeping. Same should be the case for all spares. All commissioning tests should be witnessed by TCN engineers and the Owner’s Engineer and certified by vendor and client. Similarly, all equipment which failed on testing should also be recorded for replacement. The entire process should be documented to ensure records keeping in full.

**Actions**

PMO, TCN should ensure that the Owner’s Engineer develops a process document with all templates titled as the 'Hand over Procedure' which should be reviewed and approved by TCN for implementation. All details concerning the project handover should be covered by the document and it should be widely circulated for implementation. This will ensure that the process for handing over is uniform and exhaustive without missing out on any item. The process should be tied with financial implication so that vendors also cooperate to ensure full implementation. Since there will be terminal equipment to be handed over to generating stations and distribution companies, they should also be handed the documents for proper implementation.

Finally, a centralized record keeping center like a library should be the custodian of all the project documents to ensure access for all. For spare parts, the designated warehouse should be the custodian of the material and associated record keeping. As TCN does not have a computerized process like an Enterprise Resource Planning system, the records will mostly be on standalone computer systems and accessed locally.
CONCLUSION

Nigeria being the largest economy in Africa and a major stakeholder of the West Africa Power Pool requires a robust power system which also includes a modern EMS/SCADA and communication system. Although the country has an installed generation capacity of 13,000 MW, only about 5,000 MW is successfully transmitted to electricity consumers. This level of supply is grossly inadequate for a population of over 200 million people coupled with an aging power sector infrastructure, leaving only about 50 percent of households and businesses with access to electricity, yet mired with quality and availability issues.

The FGN on its part has scaled up efforts to improve the power generation and transmission/distribution infrastructure through various investment mechanisms and groundbreaking regulations. While the necessity to possess a modern EMS/SCADA and communication system in Nigeria can never be over emphasized, it has never been a point of focus. Although efforts have been made since the nineties to set up an EMS/SCADA system in the country, it has not met the objectives and even when it was a condition precedent to start the Transitional Electricity Market in 2015, it was effectively ignored by the regulator and stakeholders. TEM was implemented without a functioning EMS/SCADA, which has given the sector the inadequacies of real-time monitoring and that have led to energy accounting disputes.

Presently, with all the issues at hand, the importance of an effective EMS/SCADA and communication system has become prominent. To this end, EDF was engaged as a consultant in 2017 to carry out a comprehensive study of the present SCADA system and make recommendations for a robust system for the future. The study has been completed and the report submitted in 2017. Since the report submission, there have been equipment modifications and additions across the network. This report can be an effective tool to scope a new SCADA system if Nigerian System Operators update the report’s findings to reflect the additions to the system since 2017. For the period, 2017 to 2021, this will require minimal updates as the majority of the system has already been documented. This will also allow the system planners to carry out all studies required for bolstering and expanding the network and provide a database for analyzing energy flow disputes and power quality issues.

The recommended actions within this report outline the process and steps required to maximize implementation gains of installing an EMS/SCADA system in Nigeria properly, effectively, and with a focus on sustainability.

A new system is only as effective as the human resources who use the system. While a new system is being procured, there must be a focus to actively involve the stakeholder team at all stages of the project, from scoping to engineering, design, testing, and commissioning to ensure stakeholders are confident to take ownership of the entire project. This is extremely important for effective operation and maintenance of all aspects of the system following handover. To realize this, human capacity building should receive special attention.

TCN has an aging workforce due to a recruitment vacuum of over ten years. A comprehensive training plan coupled with a succession plan needs to be put in place and implemented for capacity building across all levels not only at TCN but also for GENCO and DISCO company staff who are responsible for EMS assets in their jurisdiction. This will facilitate the teams to be self-reliant to operate and maintain the entire system while engaging the original vendors for major maintenance work and supply of spares.

A comprehensive implementation of the steps and processes detailed in this report will ensure Nigeria develops a functional and modern EMS/SCADA and communication system that covers the entire power network of the country while adhering to global best practices.