Design And Modeling An Automated Digsilent Power System For Optimal New Load Locations

Mohamed Saad, Mohd Ali Tofigh, Farah Zaheeda, Ahmed N AL-Masri, Nordin Bin Othman, Muhammad Irsyad, Ahmad Abbas, Erhab Youssef

Abstract: The electric power utilities seek to take advantage of novel approaches to meet growing energy demand. Utilities are under pressure to evolve their classical topologies to increase the usage of distributed generation. Currently, the electrical power engineers in many regions of the world are implementing manual methods to measure power consumption for farther assessment of voltage violation. Such process proved to be time consuming, costly and inaccurate. Also, demand response is a grid management technique where retail or wholesale customers are requested either electronically or manually to reduce their load. Therefore, this paper aims to design and model an automated power system for optimal new load locations, using DPL (DIgSILENT Programming Language). This study is a diagnostic approach that assists system operator about any voltage violation cases that would happen during adding new load to the grid. The process of identifying the optimal bus bar location involves a complicated calculation of the power consumptions at each load bus As a result, the DPL program would consider all the IEEE 30 bus internal network's data then a load flow simulation will be executed. To add the new load to the first bus in the network. Therefore, the developed model will simulate the new load at each available bus bar in the network and generate three analytical reports for each case that captures the over/under voltage and the loading elements among the grid.

Index Terms: DIgSILENT Power Factory, DIgSILENT Programming Language (DPL) , 30 bus IEEE, Power system, Load Flow Analysis, Power System

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1 INTRODUCTION
The power software's is the next generation of power system analysis tools. Power software's provides the complete assessment of system security including all forms of stability by providing a complete tool set for power system planning and operational tools. In addition to rich modeling capabilities and leading-edge computational methods, the software is highly automated and can provide engineers with significant productivity improvements. An electric power system is a network of electrical components used to supply, transmit and use electric power [1]. DIgSILENT Power Factory is leading power system analysis software for generation, transmission, and distribution of power system. It combines reliable and flexible system modeling capabilities through integrating required functions with state of the algorithms and unique database concept [2]. Power engineers nowadays in many regions of the world are using manual ways to measure substations power consumption in the distribution part of power systems for the identification of buses connected to heavy loads. Such process proved to be time consuming, costly and inaccurate at times [3]. Therefore, the use of DIgSILENT in the design and modeling of an automated power system for optimal new load locations will allow the engineers to automatically identify the over/under and loading elements in the power grid, and identifies exactly the suitable bus that can carry the new load. Therefore, the main objective of the study is to design and model an automated power system for optimal new load locations, using DPL (DIgSILENT Programming Language). This study lies in the fact that it attempts to design a DIgSILENT PowerFactory smart grid

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- *Faculty of information Science and Technology, Management and Science University, Shah Alam, Malaysia 40100*
- *College of Computer Information Technology, American University in the Emirates, DIAC, Dubai, UAE*
- *Faculty of Engineering, Helwan University, Helwan, Egypt*

related to the modeling, simulation and technical analysis of the IEEE 30 bus data as performances. Such a design will be a step forward toward replacing the manual ways currently practiced by some electrical power engineers to measure substations power consumption in the distribution part of power systems for the purpose of the identification of buses connected to heavy loads[4]. It promises to allow the engineers to automatically identify the high and low power consuming buses under a specific substation, and identifies exactly the suitable bus that can carry the new load. Such design and modeling is significant and represent a continuation of the new trend of designing customized DPL program of power software's for the management of power grids in the evolving power systems industry.

2 FROM CLASSICAL POWER SYSTEM TO SMART GRID
The attempt to design a DIgSILENT Power Factory Power grid related to the modeling, simulation and technical analysis of the IEEE's actual data will allow the engineers to upgrade the classical power system from the ground to a smart grid inside the software to perform any kind of testing, analysis and simulation which will provide accurate and economical solutions since the system is under data handling, modeling capabilities and overall functionality replace a set of other power control software systems, thereby minimizing execution costs and training requirements[2][5].

3 METHODOLOGY FOR THE IDENTIFICATION OF THE

OPTIMAL NEW LOAD LOCATIONS
Once the loads, active and reactive power injections and network parameters are defined, load flow analysis solves the bus voltages and phases, after which the branch power flow can be calculated. Generators and loads represent the boundary conditions of the solution. Mathematically, power flow requires a solution of a system of simultaneous nonlinear equations. However, with the continuous increase of power system scale, the dimension of load flow equations becomes

very high, and for equations with such high dimensions[6], we cannot ensure that any mathematical method will arrive at the right solution. Hence, choosing a reliable method is essential [7]. Therefore, the method of this study is divided into four phases mainly using DIgSILENT Power Factory software.

3.1 Data collection
Collecting the nodal admittance matrix data of IEEE 30 Bus distribution lines power system from IEEE design. This is needed in order to model the entire network with all the generators, loads and transmission lines data [8].

Fig.2 The Power Grid in the Graphic Window
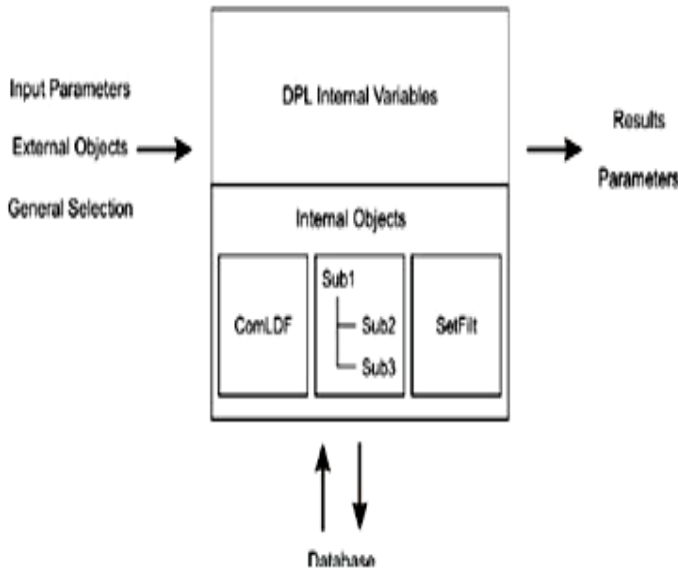
Fig.1 The Data Manager Window

3.2 Design Implementation and Load Flow Testing
The second phase consists of two main parts. First, the implementing of the design. Second, Executing the simulation of the load flow via built in command for the design to explain the load flow simulation analysis.

3.2.1 Using DIgSILENT Graphic Window to Design and Modeling The Power Grid and Executing Load Flow Simulation
In the Power Factory graphic windows, graphic objects associated with the active study case are displayed. Those graphics include single line diagrams, station diagrams, block diagrams and Virtual Instruments. Many commands and tools are available to edit and manipulate symbols in the graphics. The underlying data objects may also be accessed and edited from the graphics, and calculation results may be displayed and configured.

3.3 Identification the Optimal Load Locations Using DIgSILENT Programming Language
This phase consist of Developing DIgSILENT programming script to analyze the design and the modeling of an automated DIgSILENT power system for optimal new load locations.

A new programming script that allows the system to accept the suggested load value was developed using DPL "DIgSILENT programming language" and mathematical formulas for the buses to show the power consumption status of every single bus in the power grid.

Fig.3 Principle of a DPL Command

4 DIgSILENT PROGRAMMING SCRIPT EXECUTION
After adding the new load to the first bus bar in the grid, and executing the DPL script, the new load will be moving among all the grid's bus bars, and generates the desired reports highlighting the voltage violation overloading elements. Mainly, the structure of the DPL programming script that we developed in this study contained three parts. First, we defined the access for all objects and variables that the DPL script has as such that the database objects and their parameters become all available in the DPL script[9]. This accomplished using several methods: The most direct method is to create an object, or a reference to an existing object in the DPL command folder itself. Such an object will then be directly available as "object" variable in the script. The list of external objects is mainly used when a script is executed for specific objects or selections. The list of external objects is nothing more than a list of 'aliases'. The external object list is used to select specific objects for each alias prior to the execution of the script. This type of object is used in this study for the new load and setting the over and under voltages. We used the command "set All Relevant" to return a set with calculation relevant objects. The set of calculation relevant objects is

2

determined by the currently active study case and the currently active part of the grid which we name it buses. Objects which are out-of-service are ignored when buses=0, but are included when buses=1 or when buses is omitted. After that, we entered the return value of buses to a "for" loop which passes the new load to the buses one by one to calculate and measure the output reports as shown in Fig 4.
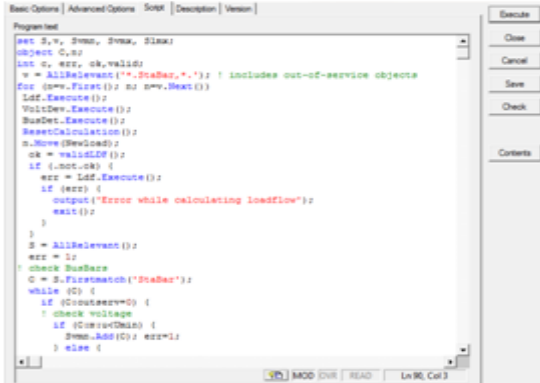
Fig.4 DPL Script lines 1-28 out of 90

As shown in Fig.4 the DPL script starting from line 1 to line 3 by defining the sets, objects and integers that are going to be used afterward. Starting by the sets which are according to IEEE 30 bus data's the minimum and maximum limits of voltage magnitude and phase angle are considered to be 0.95p.u. to 1.05p.u. and -45° to +45° respectively as shown Fig5.
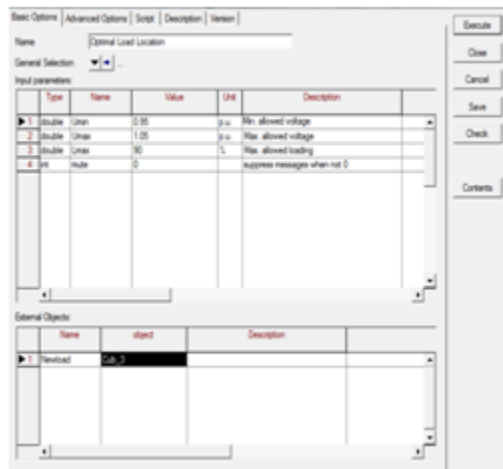
Fig.5 Input Parameters and External Objects window

Mainly the objects we are dealing with in the grid is Buses/Terminals , Generators Sync/A sync machines and Transmission lines which is internal objects as such as the external objects such as the new load that we are interested to add. In the 4th line of the script using   All Relevant('*.StaBar,*.'); DPL's Command to get all Stack Buses in the grid to include them in the following For loop which will connect the 'New Load' for the subjected bus and run the mathematical functions in the script generating all the relevant reports, After generating all the desired reports the next bus will be moving on to its turn to get the 'New Load' and indicates the grid status according to that particular bus[10].

Fig.6 DPL Script lines 29-56 out of 90

All the analytical reports that will be generated from the DPL script will be based on DIgSILENT Power Factory set of standards and trends in power system modeling, analysis and simulation

Fɪɢ.7 DPL Script lines 57-84 out of 90

Fig.8 DPL Script lines 85-90 out of 90

3

5 SIMULATION

As the planning, design and operation of power systems require load flow computations to analyze the steady – state performance of the power system under various operating conditions and to study the effects of changes in equipment's configuration [11]. This load flow study has been performed using on DIgSILENT Power Factory set of standards and trends in power system modeling, analysis and simulation. Load flow calculations are used to analyze power systems under steady-state non-faulted (short-circuit-free) conditions. Where steady-state is defined as a condition in which all the variables and parameters are assumed to be constant during the period of observation [12]. We can think of this as "taking a picture" of the power system at a given point in time. In this study, the active power and the reactive power of the loads have been set with a Characteristic so they follow a certain monthly profile. By doing so, the active power will change automatically according to the date and time we assigned. A load flow calculation determines the voltage magnitude (V) and the voltage angle (J) of the nodes, as well as the active (P) and reactive (Q) power flow on branches. Usually, the network nodes are represented by specifying two of these four quantities [13].

Depending on the quantities specified, nodes can be classified as we analyzed the grid in this study using PV and PQ nodes:

- PV nodes: here the active power and voltage magnitude are specified. This type of node is used to represent generators and synchronous condensers whose active power and voltage magnitude are controlled (synchronous condensers P=0). In order to consider equipment limits under abnormal conditions, reactive power limits for the corresponding network components are also used as input information[14].

- PQ nodes: The active and reactive powers are specified. This type of node is used to represent loads and machines with fixed values. Loads also are set to change (from their original Po and Qo values at nominal voltage) as a function of the voltage of the node to which the load itself is connected. Elements specified as PQ (for example synchronous machines, static generator's PWM converters or SVS's) can be "forced" by the algorithm so that the P and Q resulting from the load flow are always within limits[15][16].
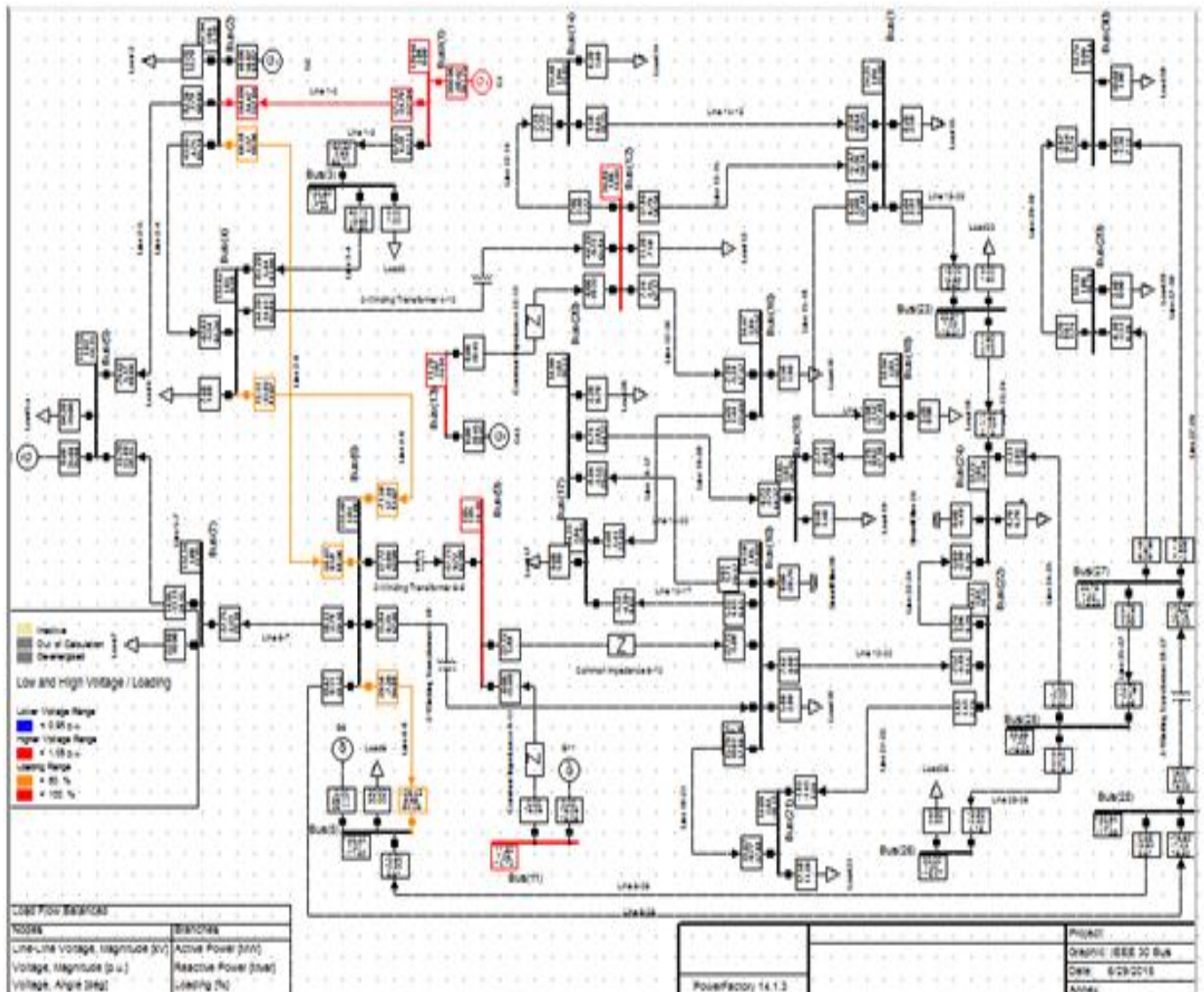
Fig.9 Graphical Representation for Loading and Over/Under Voltages in the Grid
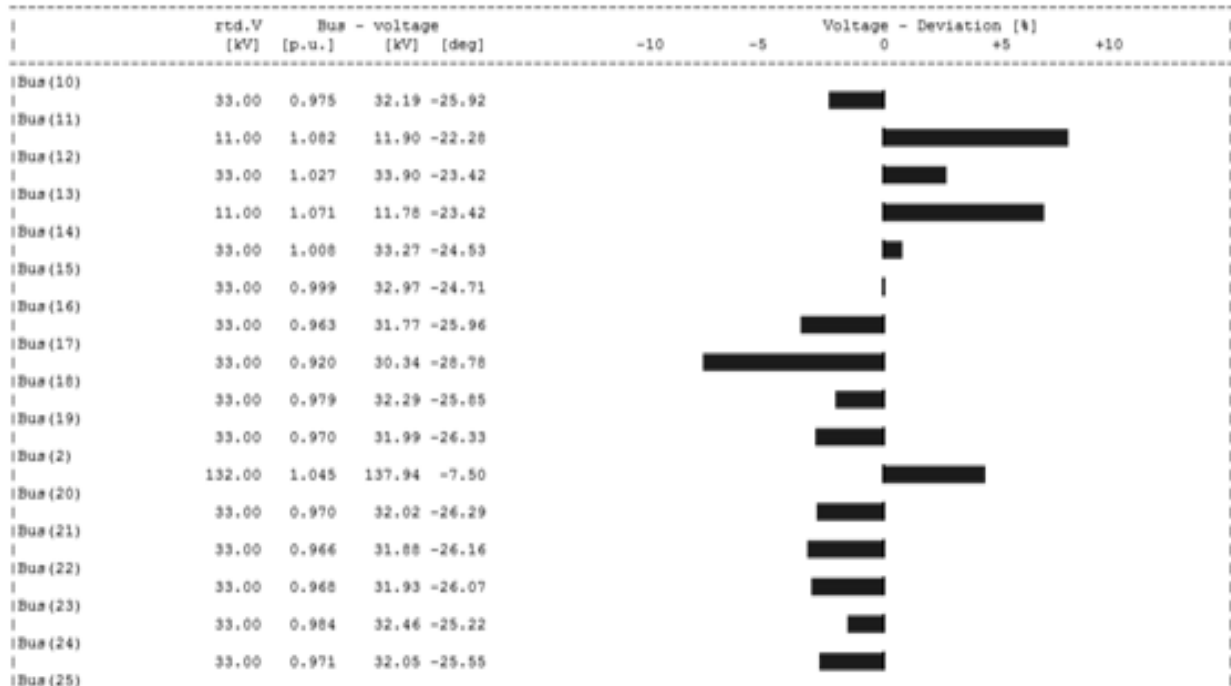
Fig.10 *Voltage Profiles Grid's Report*

Fig.11   *Buses/Terminals PQ-Report*

6 FINDINGS AND DISCUSSION

The desired output of this study is an automated DIgSILENT power system for identifying optimal locations for new loads. The starting point is collecting data of actual IEEE power system network data and the various loads connected to it. A new programming script that allows the system to accept the suggested load value is developed using mathematical formulas for the bus bars to show the power consumption status of every single bus bar in the grid. As result, the designed system has been tested for proof of concept. The bus bar identification process involved going through complicated calculation of the power consumptions in the loads, at each bus bar , and representing each bus bar status according to newton raphson algorithm power flow calculation method[17]. Therefore, the system is designed to generate three different reports for 30 different locations among the 30 bus bars in the system. The process is automatically as such that the system operator only enters the value of the new load and executes the DPL

5

programming script to generate the locations reports.

Fig.12 Grid *Summary*

Fig.13 *Grid Loading Elements*

There are three systems in this study, which are the graphical representation execution system, the DPL script management system and the data base management system. Each of these systems has been technically tested successfully. All bugs and errors are fixed and this system is now ready to be implemented.

7 CONCLUSION

An electric power system is a network of electrical components used to supply, transmit and use electric power. DIgSILENT is leading power system analysis software for generation, transmission, and distribution of power systems. It combines reliable and flexible system modeling capabilities through integrating required functions with algorithms and unique database concept. One of the applications of DIgSILENT system is the full representation of power system substations data for the management of the various control parameters and the central storage of substation related information and data [18]. Power engineers nowadays in many regions of the world are implementing manual methods to measure substations power consumption in the power systems for the identification of bus bars connected to heavy loads and the voltage violation in the grid. Such process proof to be time consuming, costly and inaccurate at times[19]. The study will enables the electrical power engineers to continuously review, manage and search the power grid with saving cost, time and maintenances with extra safety factor during the testing stage. As a conclusion, The design and model of an automated power system for optimal new load

locations, using DPL (DIgSILENT Programming Language) is a real addition in the power system management studies since it provides a lots of benefits to the power management centers specially for the grids that have a huge number of bus bars which will run the DPL script once in order to try to connect the new load manually inside the software to each bus.

8 APPENDICES

The IEEE 30 Bus Test Case represents a portion of the American Electric Power System (in the Midwestern US.Co.) as of December, 1961. The data was kindly provided by Rich Christie (1993, Aug), University of Washington and, entered to IEEE in Common Data Format. The data given in [5] is on 100MVA base. The minimum and maximum limits of voltage magnitude and phase angle are considered to be 0.95pu to 1.05pu and -45◦ to +45◦ respectively.

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