

SOFTWARE TO AUTOMATIC GENERATION OF WIND FARM APPLICATION

*Túlio Silva¹**Igor Souza Colares²**Clovis Simões³**Spin Engenharia**Queiroz Galvão Energia**Spin Engenharia*

Abstract: This work presents a new methodology incorporated to a system of supervision and control, which in the case of wind farms, automatically, generates the entire monitoring application of the wind farms, with wind turbines and anemometric towers, as well as several reports.

This methodology, called [Lean Automation](#) (LA), was used to update the SCADA software of three wind complex of a company (QGE – [Queiroz Galvão Energia](#)), automatically, generating all points of wind farms, with their addresses, alarms, events and historical records, screens and navigation rules between screens, as well as various operational reports.

With the methodology, it is possible, after appropriating the company's automation culture for wind farms, to parameterize, perform factory tests and commission the wind farm in record time, at a much lower cost, with quality and with minimal error possibility.

Keywords: SCADA; Wind Farm; anemometric towers; Wind Farm Concentrator; Protocols; Lean Automation.

1. Introduction

From 2013 until now (2019), QGE implemented five wind complex located in three different states of northeast of Brazil. Each complex has local control that concentrates data from wind farms and substations and sends them to an Integrated Operation Center (IOC), located in Fortaleza, CE [1]. This center, in addition to the wind complexes, also controls four hydroelectric plants, distributed in other three states of Brazil.

Both wind farms and hydroelectric plants are unattended sites, operated remotely from the IOC, reducing the system's operating cost by about 89%, as well as standardizing operating and maintenance procedures. Centralization also homogenizes how historical data is handled, since all are in the same relational database, in this case MSQ Server, allowing standard handling of this data for the generation of dashboards and KPIs.

The operating center model adopted by QGE is somewhat different from usual, integrating in the same system, IT infrastructure assets, substation assets and, wind assets (wind turbine and anemometric towers). Today, the installed capacity of the assets controlled by the IOC of Fortaleza is 1,032 GW, of which 712.2 MW are wind complexes.

2. Technological Update of Wind Power Plants

In 2018, the QGE decided to make the technological upgrade of all wind complexes, three of which, Icaraí, Taiba and Caldeirao Grande, have already been made.

This update was motivated by several factors, among which we listed the main ones:

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- 1) Enhancements to the IEC61850 protocol: The existing protocol was upgraded to include the new protocols standard as well as the code were changed from C++ to C#. With the new protocol, we obtained:
 - a. The increase of speed connection;
 - b. Signaling of buffered events;
 - c. Decreased traffic in the SCADA network;
 - d. Possibility of extracting COMTRADE files;
 - 2) Alarm Analysis Screens: with the addition of new alarm functionality by areas, it became possible to analyze alarms actuated in real time by predefined areas such as lines, transformers, auxiliary services; collector circuits, etc., as well as alarmed alarms that are still active and not recognized.
 - 3) Improvement of historical data queries, making them faster, for large volumes of data, with the possibility of, in addition to selection by bays, making the selection by category (analog and digital). In historical queries, besides the values you can also see the average, the maximum and the minimum.
 - 4) Improvement of the functionalities of the trend graphs in real time and historical, allowing to see the values plotted at any time on any axis.
 - 5) Addition of annotations with operation records made by operators.
 - 6) Addition of a new real-time diagnostic module of the SCADA system by an observer module.
 - 7) Introduction of the [component concept](#), which is a functional cell of a SCADA application, which allows the automatic generation of a set of functionalities in a single mouse click. This concept, detailed below, is the backbone of the LA methodology.
Thus, after developing an application that implements the supervised control of a wind farm, using wind turbines or Suzlon S95 or GE / Alstom ECO-122, and anemometric towers that use the same sensors, it is possible to generate other parks with the same characteristics, in record time, with the same quality of previous parks and without errors.

3. Concept of Components and Methodology Lean Automation Applied to Wind Farms

A cell from an LA application is called a component. The empty design of the SCADA adds components that allow generating a wind farm with a few clicks.

The first component of the application contemplates several reports common to this type of application: (1) Current alarms; (2) Events of the day; (3) Operation Log; (4) Query of historical events; (5) Query of system tags, by hierarchical level; (6) Real-time and historical trend graph of selected variables; (7) Annotations Report; (8) Viewing the SCADA diagnostic module.

The second component corresponds to the SCADA diagnostic module that monitors the hot-standby servers that control the substation and its wind farms.

The third component added allows the creation of wind farms with the Suzlon S95, GE / Alstom ECO-122 wind turbines and anemometric towers.

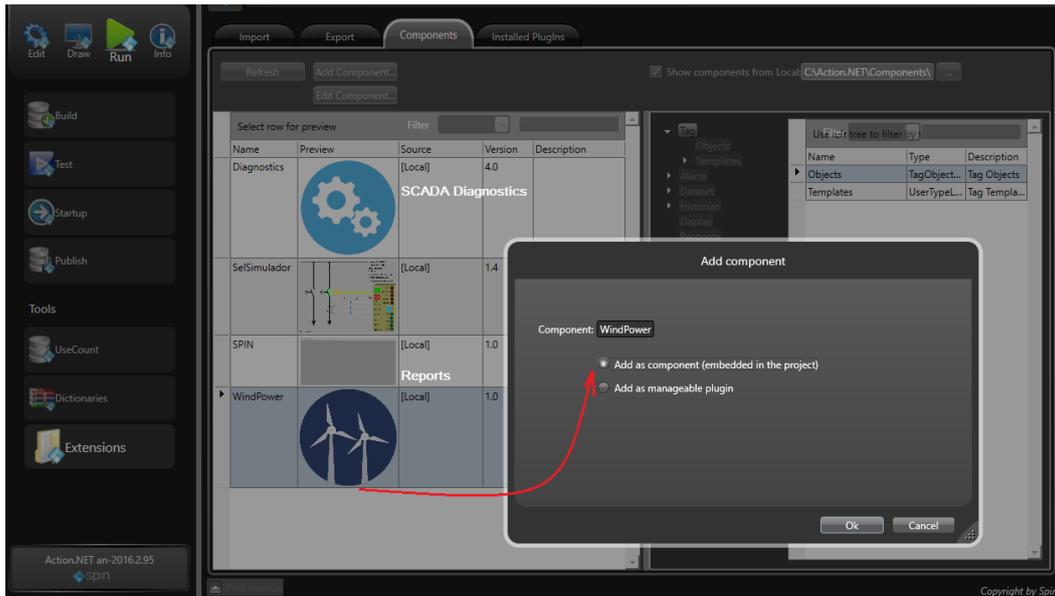


Fig.1 – Components used in the Wind Power application

In addition to deploying solutions in record time and minimizing errors, the component guarantees the maintenance of process knowledge in the solution, and not only in the company's technicians. Thus, for example, the "[Wind Power](#)" component implemented in the QGE implements the monitoring of wind farms, meeting all requirements of the regulator agent. Its creation is based on the implementation of more than 1 GW of wind power in different wind farms.

A manufacturer or consultant to establish the best practices of using any equipment, such as a wind turbine, a relay line, etc., can use the component container. Thus, the developer uses all the features available in the equipment, to get the best of it and thus sets this knowledge in a component that will be used in dozens of projects, ensuring best practices for the use of that equipment.

4. Example of Using Lean Automation to Generate Wind Farms

4.1 Summary of the implementation of an LA application

To facilitate the understanding of the application, we will exemplify it in the generation of wind farms composed of an anemometric tower and some wind turbine circuits. In most of the deployments we participate in, a circuit has between five and six wind turbines and one farm usually has two circuits (10 to 11 wind turbines) and an average power of 25 MW.

This [example application](#) is based on deployments made and in the example, we will use wind turbines of two models and identical anemometric towers in all farms.

4.2 Identification of application templates

In this base application, we will have five basic templates:

- 1) Template 1: ECO-122 wind turbine (GE/ Alstom);
- 2) Template 2: S95 wind turbine (Suzlon);
- 3) Template 3: Anemometric Tower;
- 4) Template 4: GE/Alstom wind farms. An ECO-122 park has a single data concentrator with OPC protocol that contains the structure of the wind turbines (template 1) that is repeated for the total of the wind turbines of the farm and the data structure of the park, which contains totals of a group of wind turbines (template 4);

- 5) Template 5: Suzlon wind farms. Each farm has a distinct Modbus data hub, with global farm data and data from each wind turbine associated with that farm.

For each template we group all the tags of the represented element, identifying for each tag the rule to create that individual item of the template, the conditions of associated alarms, whether the same goes for historical and the associated trigger and the address of the point in the IED where it is located.

In addition to the templates that describe points associated with IEDs, we may have other logical structures with calculated logical point groupings.

If, instead of a wind farm, we had a substation, the structures would be the substation type bays, such as line bay, transformer bay, capacitor bank bay, etc.

The figure below, for example, shows three templates, one for the anemometric tower data structure, one for the data structure of the ECO-122 wind turbine and one for the wind farm with all ECO-122 wind turbines

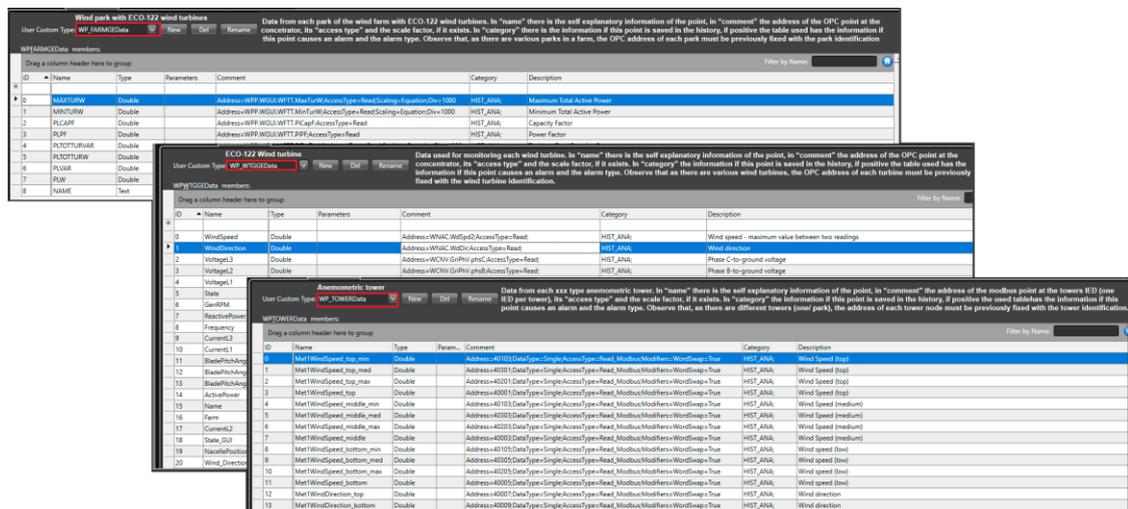


Fig.2 – Templates for a Wind Farm with Wind Turbines ECO-122 and Anemometric Towers

4.3 Creating the objects associated with the basic templates

In the base component, for each type of object, comes an example line of how to define this object. The figure below shows the description of a GE wind farm with two anemometric towers and six ECO-122 wind turbines. Note that in the object description, there is a naming rule of the object according to the client definition, and the type of the object corresponds to the type defined in the template for that object.

In the "Comment" column are defined prefixes that are concatenated and added to the addresses of the points of the towers and wind turbines. That is, each tower has the same address associated with the same point, and a prefix must be added that will differentiate one address from the other. The same is true for wind turbines.

Drag a column header here to group

The object type is the name of the template that describes it

Name	Type	Retentive	Comment	Level	Category	Description
FARM_GE	WP_FARMGEData	None		FARM	NODE_FARMGE;	FARM_GE
TOWER1	WP_TOWERData	None	NodePrefix=TOWER1_	FARM/TOWER	NODE_MOD;	PGE01:TOWER1
TOWER2	WP_TOWERData	None	NodePrefix=TOWER2_	FARM/TOWER	NODE_MOD;	PGE02:TOWER2
WP_GE01	WP_WTGGEData	None	AddressPrefix=GE01.	FARM/WTG	NODE_FARMGE;	PGE01/WP_GE01
WP_GE02	WP_WTGGEData	None	AddressPrefix=GE02.	FARM/WTG	NODE_FARMGE;	PGE01/WP_GE02
WP_GE03	WP_WTGGEData	None	AddressPrefix=GE03.	FARM/WTG	NODE_FARMGE;	PGE01/WP_GE03
WP_GE04	WP_WTGGEData	None	AddressPrefix=GE04.	FARM/WTG	NODE_FARMGE;	PGE02/WP_GE04
WP_GE05	WP_WTGGEData	None	AddressPrefix=GE05.	FARM/WTG	NODE_FARMGE;	PGE02/WP_GE05
WP_GE06	WP_WTGGEData	None	AddressPrefix=GE06.	FARM/WTG	NODE_FARMGE;	PGE02/WP_GE06

Find window

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In this example there is a farm (FARM_GE), two towers and six wind turbines

Observe that:

- In Level we have FARM/TOWER/WTG
- As there are 6 GE wind turbines, the OPC address of each wind turbine will be previously fixed with the wind turbine identification (GE01, GE02, Etc.)
- As there are 2 towers with 2 IEDs Modbus, each tower node will have as prefix the tower identification:
TOWER1_NODE_MOD
TOWER2_NODE_MOD
- As there is only one GE concentrator, its identification is NODE_FARMGE

Fig.3 – Objects created from the templates (one farm, two towers and six wind turbines)

4.4 Creation of the Draw Library

For each type application, generated through LA, a library of symbols is created that will be used in all the screens that allow the monitoring and control of the represented elements. Thus, for each type of wind turbine, tower, park, etc. symbols will be created and placed in the library.

These symbols automatically generate references to their associated objects so that if I copy a WP_GEO01 object, in the objects column (see figure above) and paste on a drawing screen, all variables associated with that instance of the object are mapped for this symbol. That is, the power generated by that wind turbine is the power of the WP_GEO01, and the same goes for its current, its state, etc.

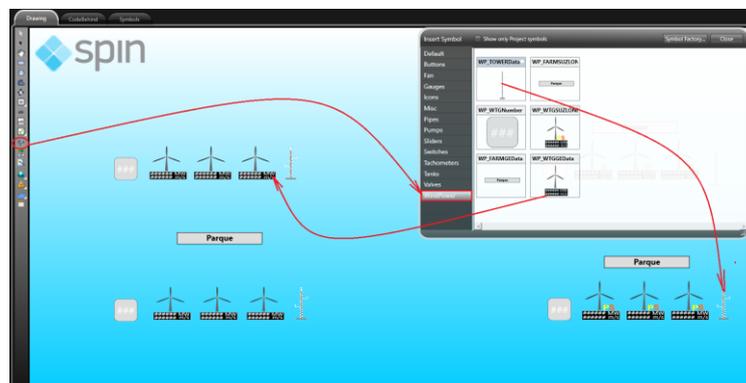


Fig.4 – Symbol library of a Wind farm

In the figure below, using an LA library to generate utility substations, the copy of the CAX_21P1 feeder line of objects and their paste in a drawing screen.

All animation rules are already made in this feeder symbol:

- A click on the feeder name takes us to a feeder details screen;
- A click on the circuit-breaker and switches opens a control window of the equipment;
- A click on the feeder current opens a window with the current in the three phases;
- A click on the adjustment tables allows us to change the feeder relay settings;

- A click on the feeder protection allows us to inhibit, block, or simulate, the protection.

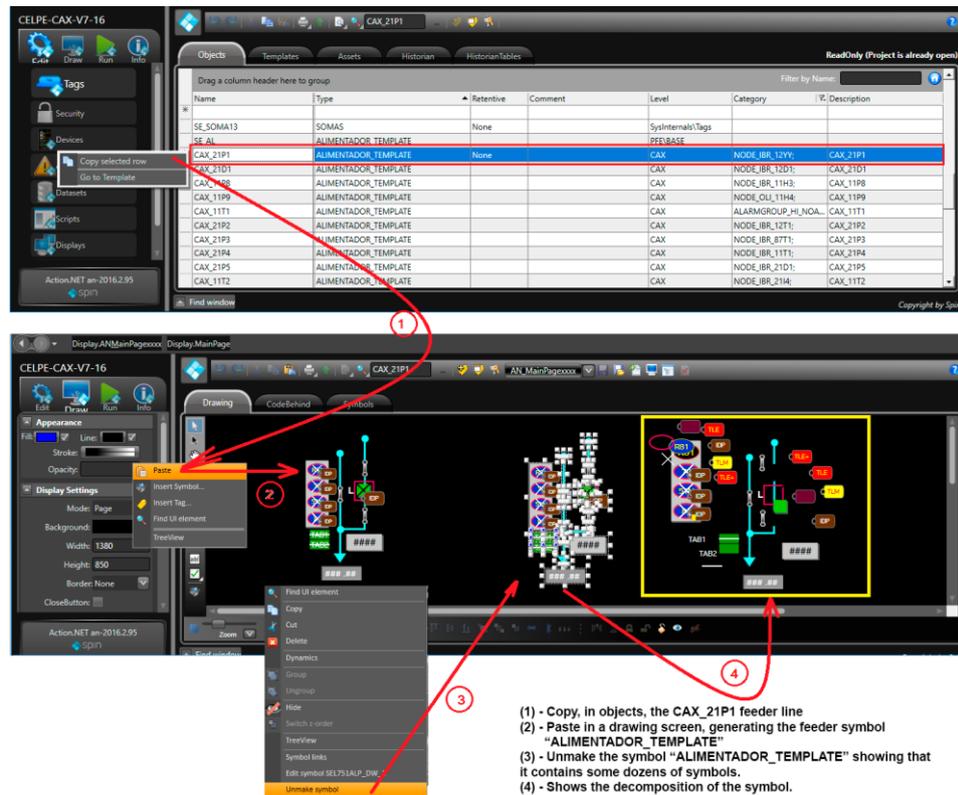


Fig.5 - The CAX_21P1 object turns into a drawing of a feeder bay

4.5 Creating Application Screens

Then, after we create the base application templates and the objects associated with these templates, the application screens are created. For example, in the case of wind farms, seven base screens have been created in addition to the existing reports in the empty project (see item 3). These screens are:

- (1) Screen of the example wind complex, with four wind farms. Each farm has three wind turbines, an anemometric tower, a symbol that informs the number of wind turbines in operation at the moment and a button that allows navigating to the totals of the farm concentrator. This screen is created at application time, while the others are already pre-ready and are accessed from generated links in the symbols.
- (2) Details of an ECO-122 (GE / Alstom) wind turbine. If the mouse passes over a wind turbine, its figure is modified to a hand and if it is clicked, it navigates to the detail screen of that wind turbine.
- (3) Details of an anemometric tower. The operation is similar to that of the wind turbines, click on a specific tower and navigate to the screen detail of the selected tower.
- (4) GE / Alstom wind turbine details. This screen contemplates the production totals of GE / Alstom wind generators that are all in a single data concentrator (OPC protocol).
- (5) Details of a Suzlon concentrator of wind turbines. Differently from GE concentrator, where we have one concentrator for all farms, the Suzlon solution has one concentrator for each wind farm. If we want to make a totalizer of all Suzlon wind farms (sum of the two parks), we must create a new logical structure.
- (6) Details of an S95 (Suzlon) wind turbine, selected in the same way as ECO-122 wind turbines [2] [3].

(7) In the case of S95 wind turbine, they have an alarm indicator that identifies dozens of possibilities, with a description of the fault, corrective actions and suggestions.

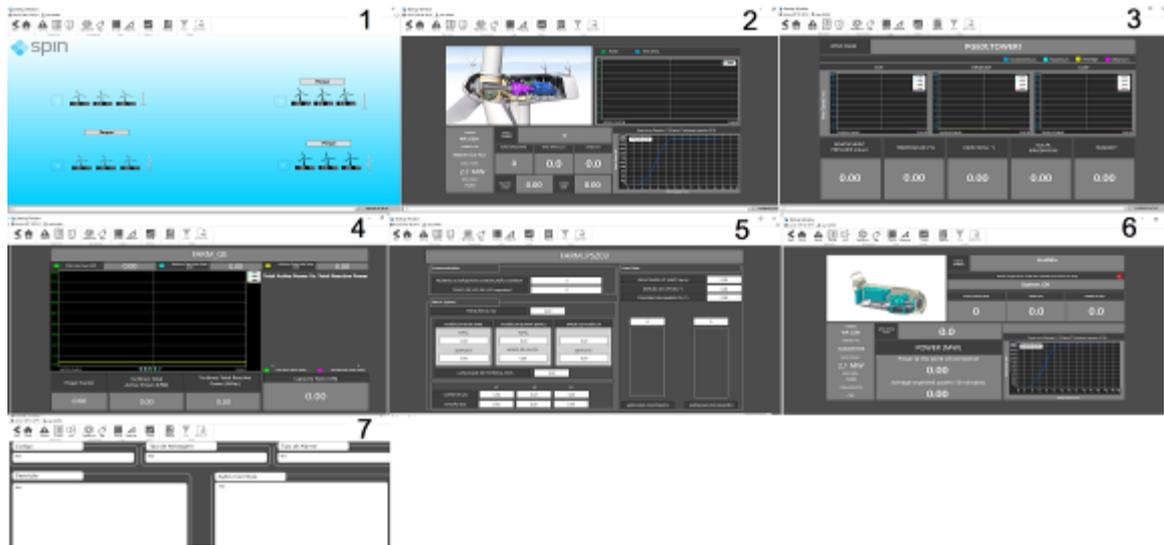


Fig.6 – Screens of wind farm application (Example)

For each type of application, it is made a planning of these screens and their navigation, always attending the client's operational culture. Once the base application is tested, new applications are generated in record time, with quality, robustness and no errors.

4.6 Creation of channels and associated nodes

For each IED of the project should be created channels and nodes that will allow the connection with them at run time. In the case of the example application, according to the figure below, we will have seven channels, 1 OPC and 6 Modbus.

As in the address of the points the prefix of the node associated with the point must be added, in order to identify the associated IED, these prefixes must be included in the comments of the respective objects (see figure 3 - Comments).

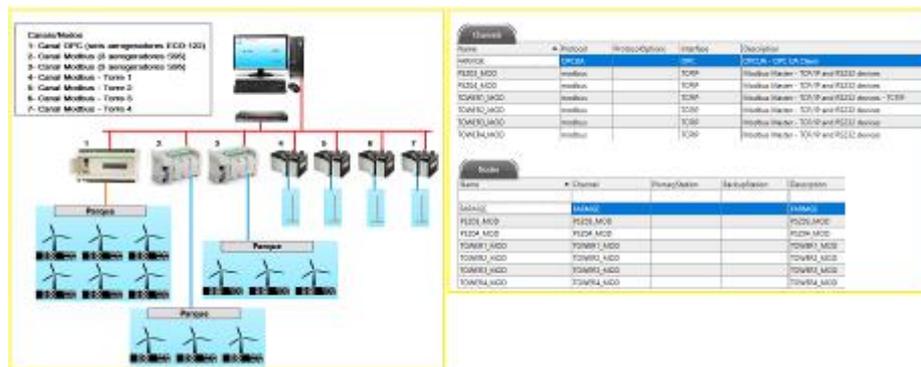


Fig.7 – Channel and nodes of the application

4.7 Deploy – Instantiation of alarms, addresses and history records

In the sequence, after all the previous steps we execute the Deploy that instantiates all the items associated with each tag. Deploy is one of several programs available in a library of extensions of the SCADA, which at project time, allow you to import, export and process data associated with the application. In the specific case of this program, when executed it scans the Tag/Object lines (figure 2) and, for each line that has objects to be exploded (category and

comments), it explodes automatically generating the items of the alarms, history, and Input/output points associated with the template. After the explosion, it deletes the categories and comments associated with that line, allowing in the future, when creating a new object, only this one to have its data instantiated.

As an example, considering the wind farm, for each object created (wind turbine, anemometric tower, wind farm, etc.), the alarm tables, history and associated I/O addresses are generated.

4.8 Generation of the Main Screens of the Applications

As shown in the item above (4.5), the base screens are pre-made and assume the reference element when called, for example, there is a feeder detail screen that when called from a given feeder, assumes the reference of the same, as well as wind turbine, anemometer towers, etc.

On the other hand, the main screens of the application, as a given substation, a wind farm, etc. are generated in each repetition of the process. Thus, the last step of the application is to copy all objects created on the object screen and paste them into one or more drawing screens, as shown in the items above (4.4 and 4.5).

Once these procedures are completed, the application will be ready and, if the base application tests have been well done, the generated applications will be error-free and generated in record time.

In IEDs with fixed addresses, such as concentrators of wind turbines and wind farms, anemometric tower concentrators, multi meters, etc. all addressing will be 100% correct after testing the base application, also allowing process knowledge to stay in the application rather than the staff. That is, anyone can generate a correct application, without ever having worked in this process or with these IEDs.

5 Conclusions

This methodology is under patent process at INPI and has already been applied in several automation projects of electrical systems such as automation of utility substations and wind farms.

The figure below shows QGE park screens generated using Lean Automation technology using both Suzlon wind turbines and GE / Alstom.

Finally, we just finished a new component that calculates indicators of asset availability of substations and wind farms. Using this new component, the wind power component and the industrial substation component, we create one application that generates several [reports to optimize Wind Farms](#) operation and production.

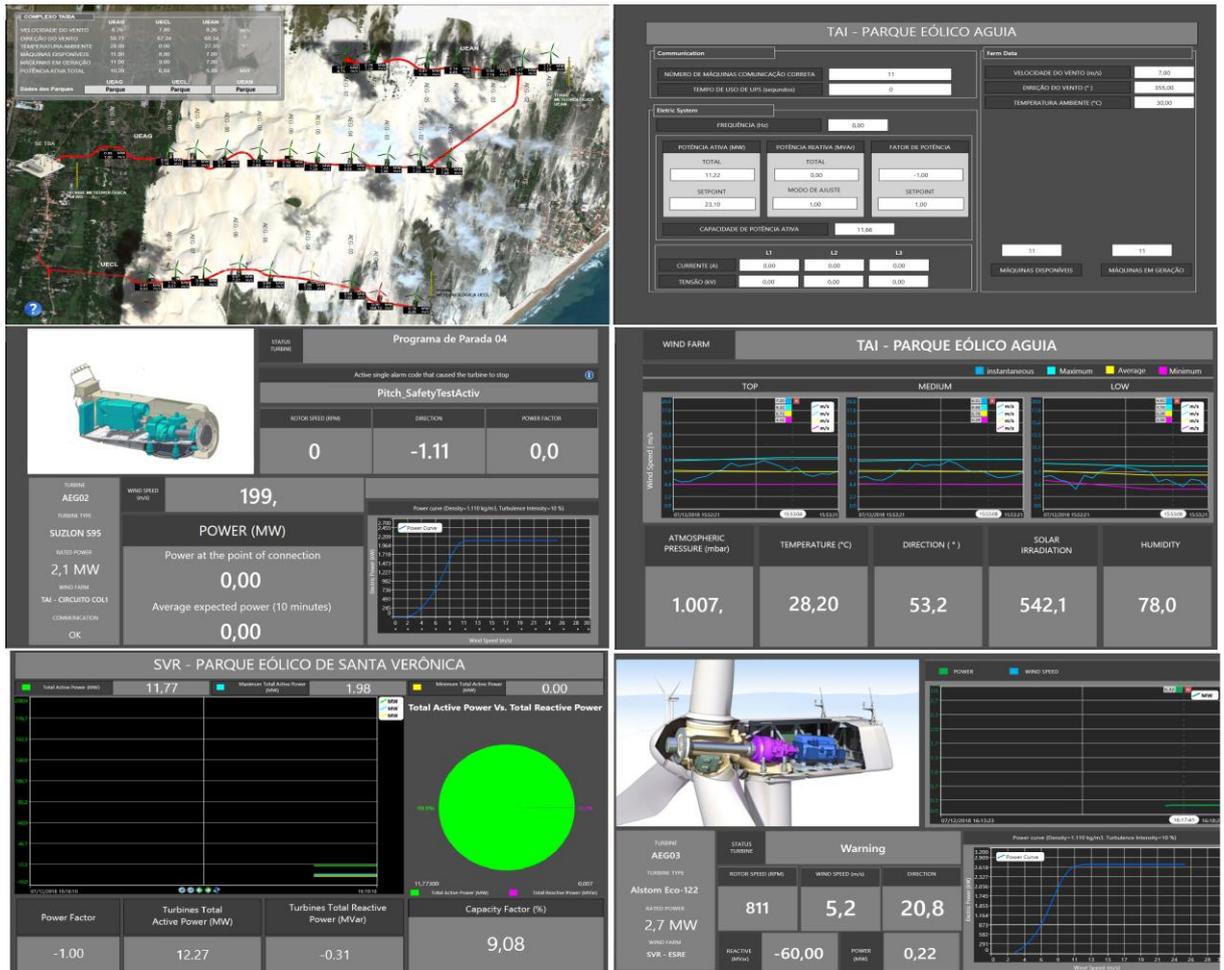


Fig.8 – Applications screens generated using LA technology

6. References

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