1. INTRODUCTION

The fundamental nature of an electrical power system is changing with the inclusion of photovoltaic (PV), which stochastic character and great number of units connected to the grid is likely to cause voltage regulation problems, making their control of deep interest to utilities [1,2].

Specific interest has been shown about the stalling phenomena of HVAC induction motors due to voltage sags which could negatively affect the post-fault voltage recovery. As the motor stalling can be registered in cycles, reactive power injection from PV may constitute a fast mechanism for voltage regulation [3].

An overall solution can be found in the application of artificial intelligence M.A.S., that would allow to automate decision-making processes through the use of intelligent and autonomous devices called agents, increasing the reliability of the system and reducing operating costs. The application of M.A.S, and advanced PV control to enhance voltage stability after fault occurrence is a promising area where few researchers have contributed [4].

2. MULTI-AGENT SYSTEMS (M.A.S.)

A multi-agent system (M.A.S) is simply a system comprising two or more agents. The M.A.S. does not have an overall system goal, instead the local goals of each separate agent. An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it. An agent has the following characteristics: Autonomy, Social Activity, Reactivity and Pro-activeness [4, 5].

The architecture of M.A.S. systems can be Centralized (traditional zone based-control strategies), or Distributed, (knowledge about its own part of the network) [6, 7, 8]. In this research, Distributed architecture with two hierarchies was applied. Two agent types were designed for this system:

- Monitor Agent: to keep continuous record of the desire variable.
- Action Agent: Responsible for monitoring and commanding actions on the PV according to the outputs of the monitor agents.

Figures 1 and 2 show the flowchart of how the Monitor Agents takes decisions. Figure 3 shows the Action Agent decision flowchart.

3. DESCRIPTION OF THE POWER SYSTEM

The system under study is a typical distribution feeder 14.4 kV, radial type, with an impedance equivalent to 10 miles from the source. The load is modeled by static load and motor type load concentration in four nodes, served each one from a transformer single phase, 14,400/120-240 V.

The PV units are connected in 240V. Figure 4 represents an equivalent of the system studied. The size of the PV array is 50% of the load in each node, and it is set to operate with unity power factor in steady state. During the fault, the PV can inject reactive power to support the voltage.

The power system was modeled using PSCAD and the M.A.S. was coded in MATLAB and UMAP. Figure 4 also shows the location of each agent.

4. SCENARIOS AND RESULTS

Three different cases were defined: Case 0 No PV integration (green), Case 1: PV with standard settings (blue) and Case 2: PV controlled by M.A.S (red).

A double line to ground (LLG) fault in the transmission system was simulated for each case at 1.5 seconds and the dynamic response of the system was studied. The variables analyzed were: The Feeder Voltage (Figure 5), The Motor Speed (Figure 6), The Motor Power (Figure 7) and the PV Power injected to the system (Figure 8).

The fault generated a voltage drop on the feeder of 0.47 p.u. (Figure 5), which caused the stalling phenomena of the motor load. Case 0 (green) Figure 6, shows how the motor speed decreased due to the fault while the motor power (Figure 7 – green) increases to 4.1 times the nominal power of the motor. This condition affects the post-fault voltage recovery due an increment in active and reactive power load of the load.

In Case_1 (blue) shows the contribution of the PV reactive power injection during the fault (Figure 8-blue), however, depending on the type, duration and location of the fault, this contribution may or may not be enough to avoid the stalling phenomena of the motor. In this case, the PV contribution is fairly enough presenting the stalling phenomena is present for 1.2 seconds (75 cycles) delaying the post fault voltage recovery (Figure 5 – blue).

5. CONCLUSIONS AND RECOMMENDATIONS

In this research, the application of Advanced PV Control and M.A.S. for distributed control was developed to improve short-term voltage stability during fault condition, specifically oriented to avoid HVAC motor stalling. The results show that with the application of M.A.S. it is possible to increase the aggressiveness of the PV during the fault occurrence, generating a faster recovery of the motor, thus, the feeder voltage. The project demonstrated that the electronic equipment associated to PVs, such as DC/AC inverters, can be effectively used as a fast-response reactive power injection.

Future work may consider to study more aggressive types of fault to determine under which cases this contribution can be suitable on distribution systems.

6. REFERENCES


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