SHORT-TERM VOLTAGE STABILITY ENHANCEMENT USING ADVANCED PV CONTROL AND M.A.S. IN DISTRIBUTION FEEDERS

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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-taking 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].

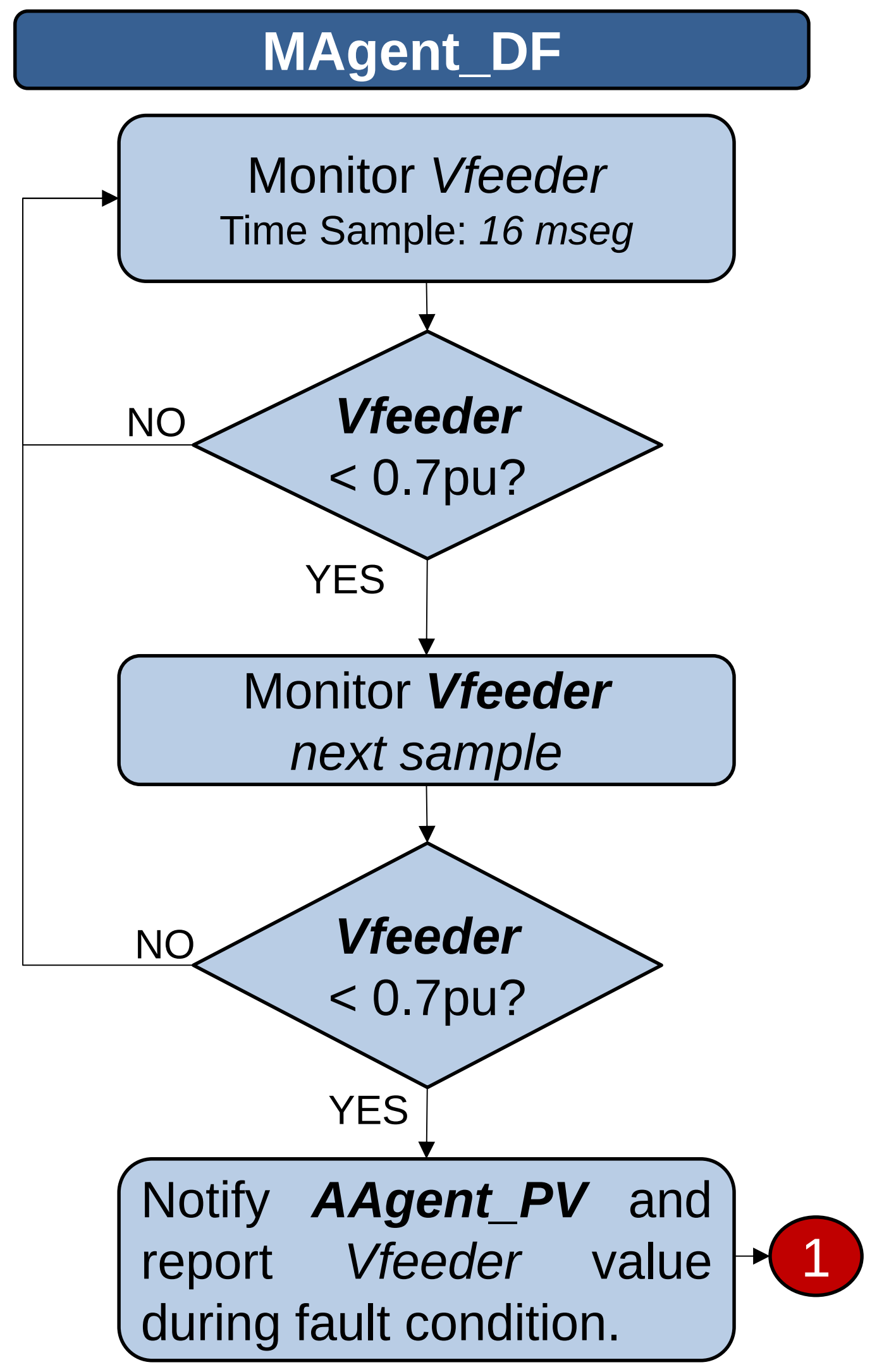
2. MULTI-AGENT SYSTEMS (M.A.S.)

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 Ability, 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 hierarchic levels* 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.



MAgent_DF

Monitor *Vfeeder*
Time Sample: *16 mseg*

Vfeeder
< 0.7pu?

NO

YES

Monitor ***Vfeeder***
next sample

Vfeeder
< 0.7pu?

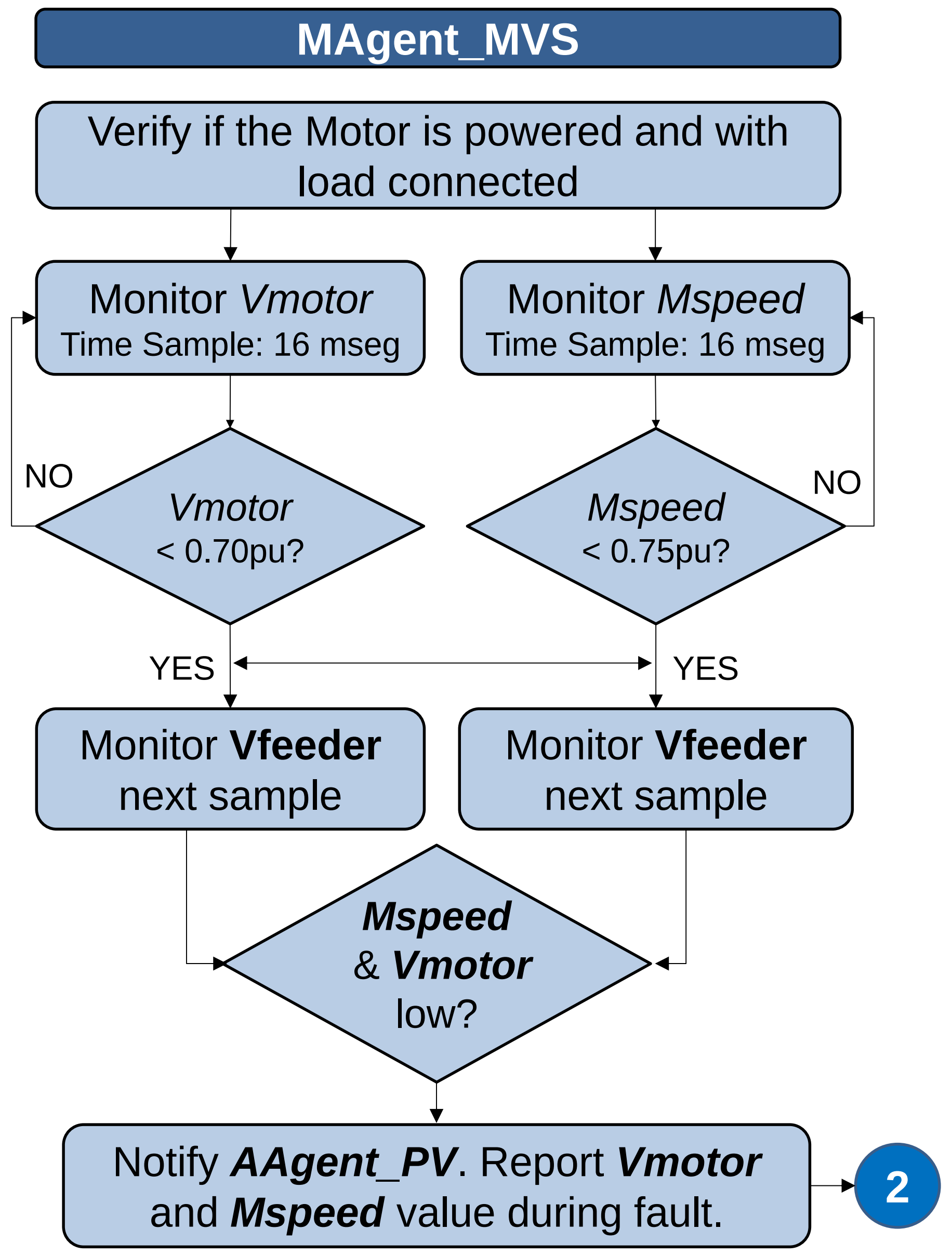
NO

YES

Notify ***AAgent_PV*** and report *Vfeeder* value during fault condition.

①

Figure 1. MAgent_DF Flowchart



MAgent_MVS

Verify if the Motor is powered and with load connected

Monitor *Vmotor*
Time Sample: 16 mseg

Monitor *Mspeed*
Time Sample: 16 mseg

Vmotor
< 0.70pu?

Mspeed
< 0.75pu?

NO

NO

YES

YES

Monitor **Vfeeder**
next sample

Monitor **Vfeeder**
next sample

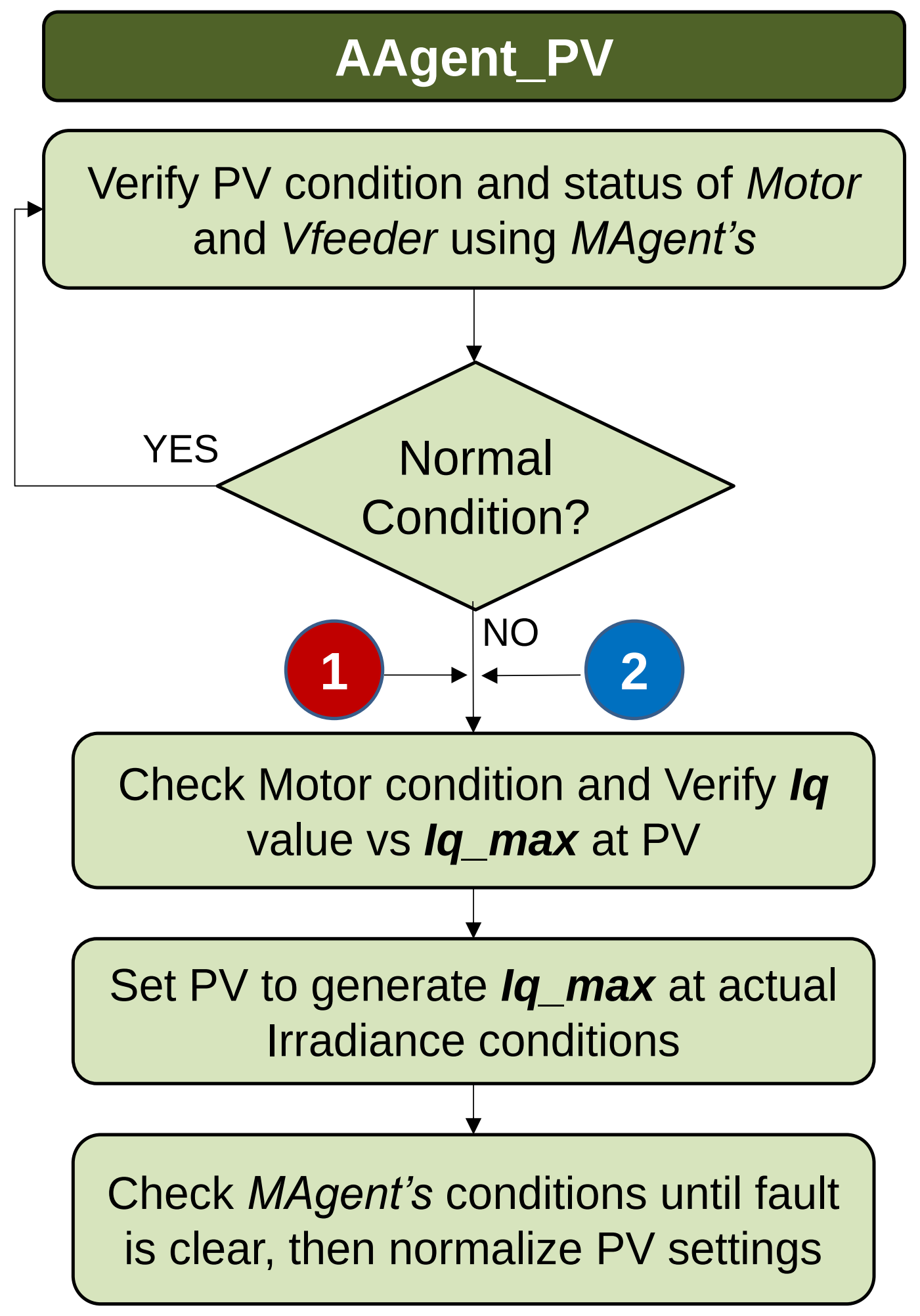
Mspeed
& ***Vmotor***
low?

Notify ***AAgent_PV***. Report ***Vmotor*** and ***Mspeed*** value during fault.

②

Figure 2. MAgent_MVS Flowchart

Table 1 shows the types of agents associated to each element on the power system studied:



AAgent_PV

Verify PV condition and status of *Motor* and *Vfeeder* using *MAgent's*

Normal
Condition?

YES

NO

①

②

Check Motor condition and Verify ***Iq*** value vs ***Iq_max*** at PV

Set PV to generate ***Iq_max*** at actual Irradiance conditions

Check *MAgent's* conditions until fault is clear, then normalize PV settings

Figure 3. AAgent_PV Flowchart

Table 1. Agent Types

Element	*Agent Type*	*Agent ID*	*Variables to Monitor*
Distribution Feeder	Monitor	*MAgent_DF*	Feeder Voltage.
HVAC Motor Load	Monitor	*MAgent_MVS*	Voltage, Power & Motor Speed.
PV	Action	*AAgent_PV*	Current Injection

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.

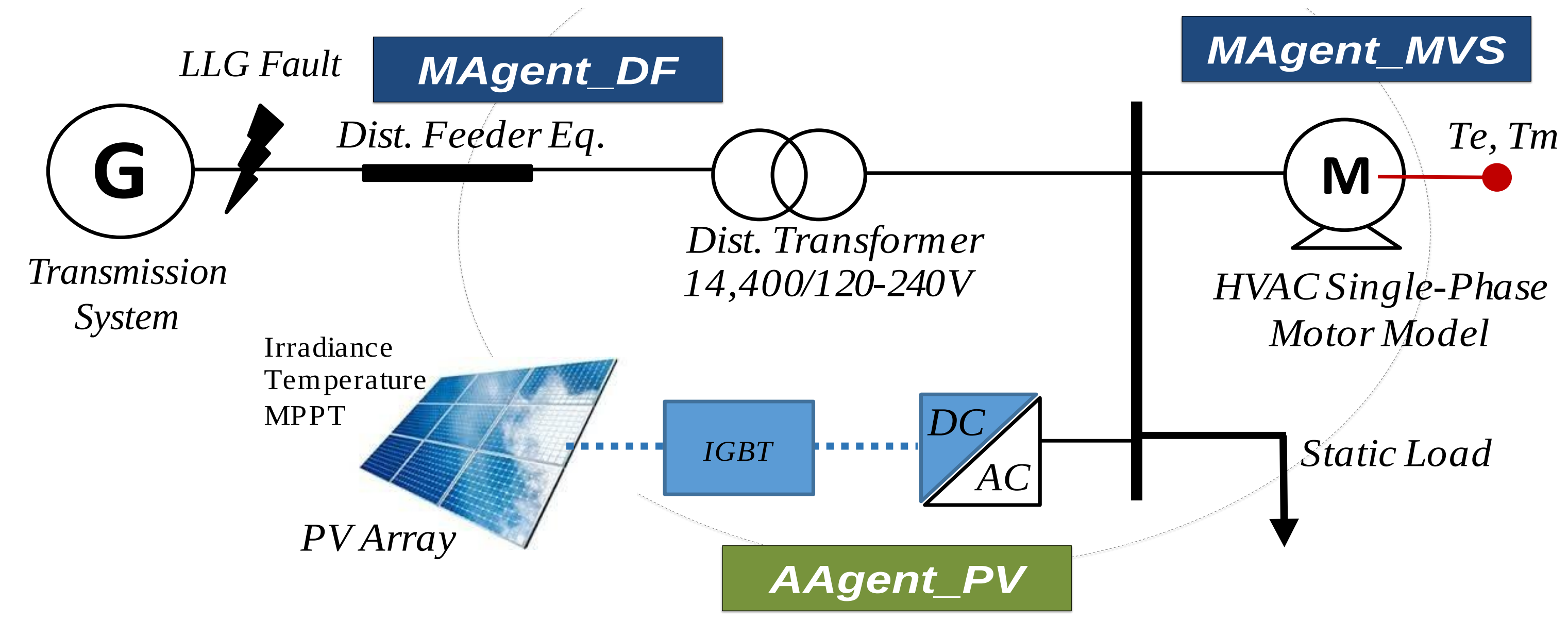


Figure 4. Power System representation and M.A.S. agents location

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 demand 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, location and duration 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).

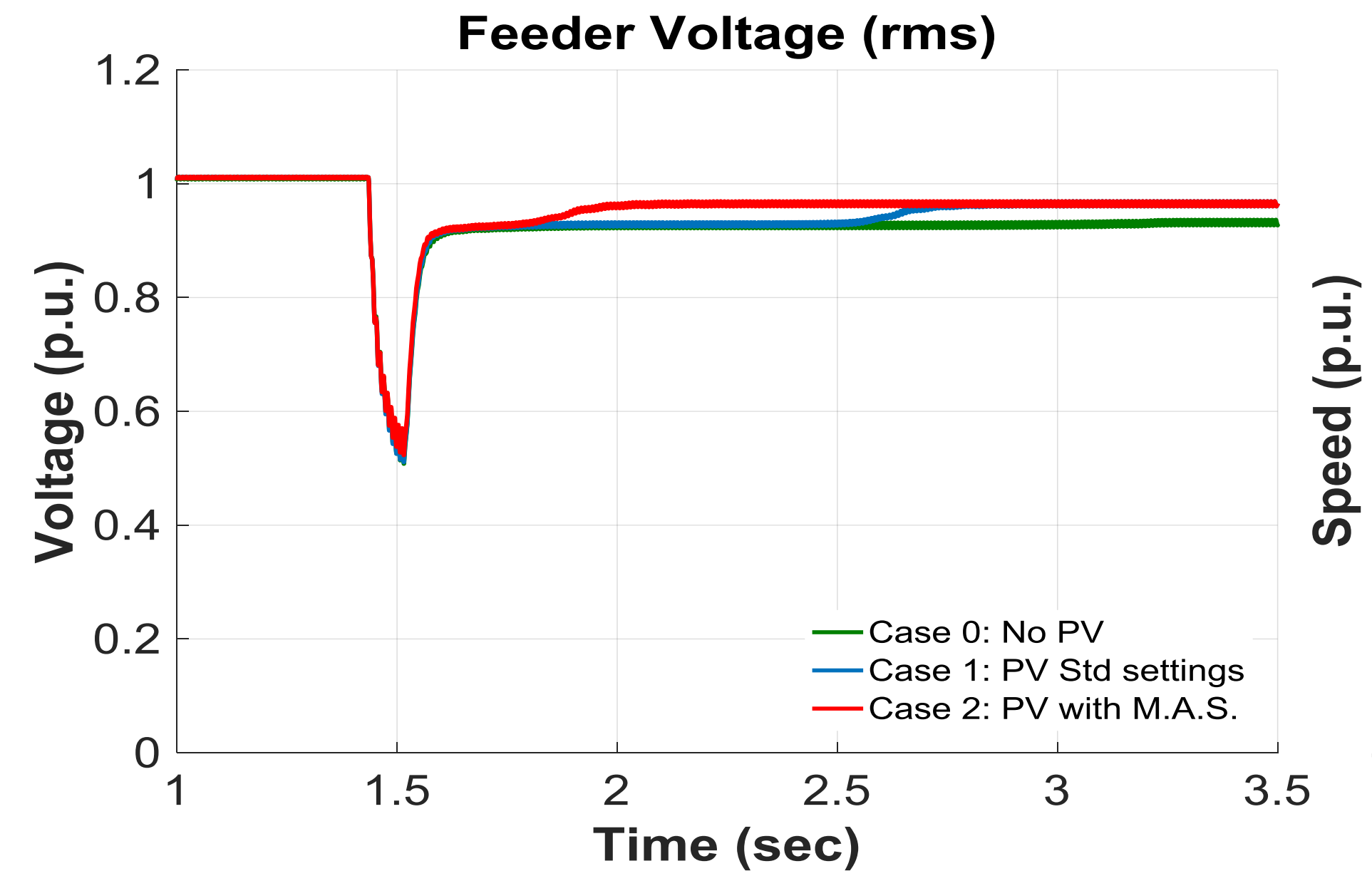


Figure 5. Feeder Voltage

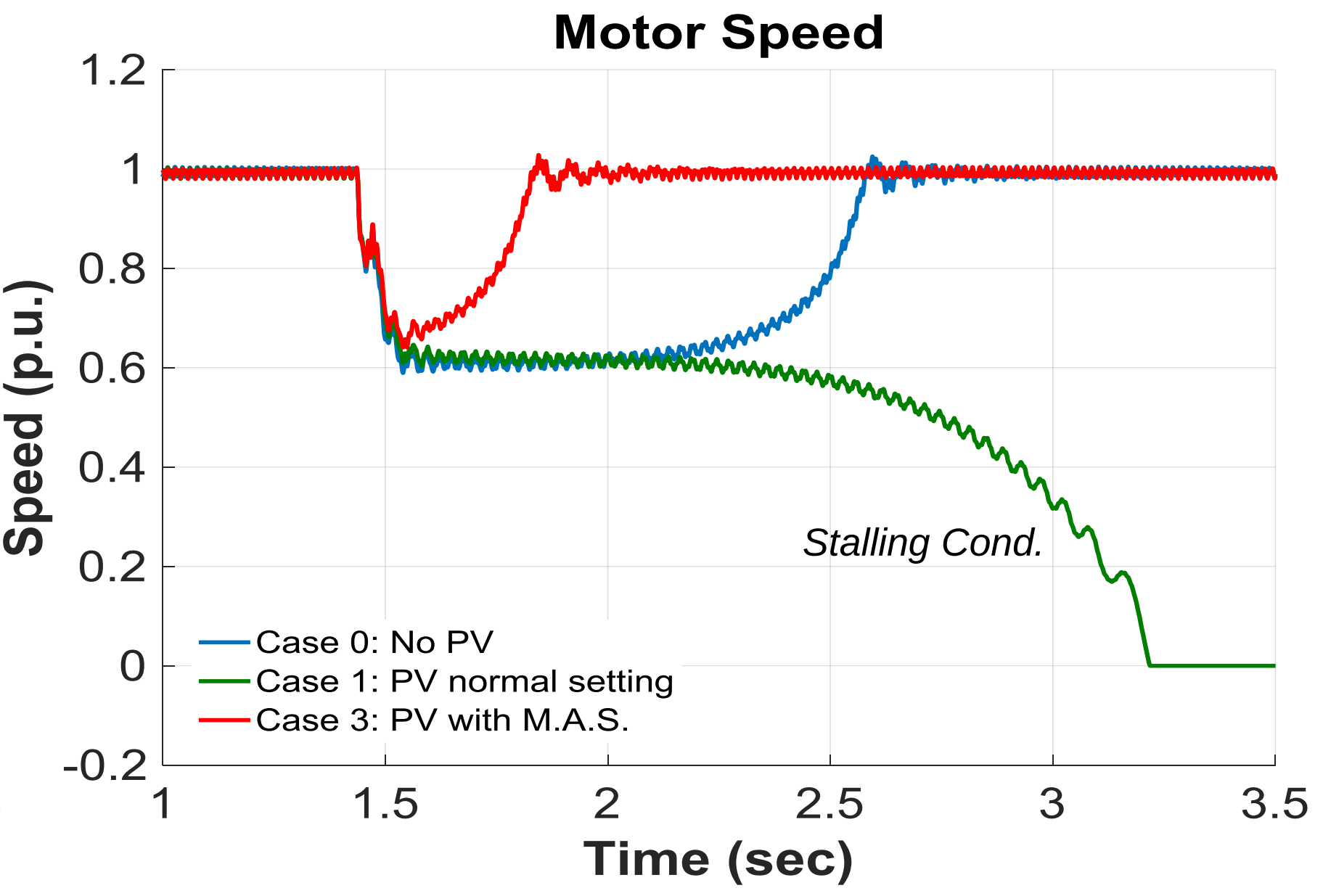


Figure 6. Motor Speed

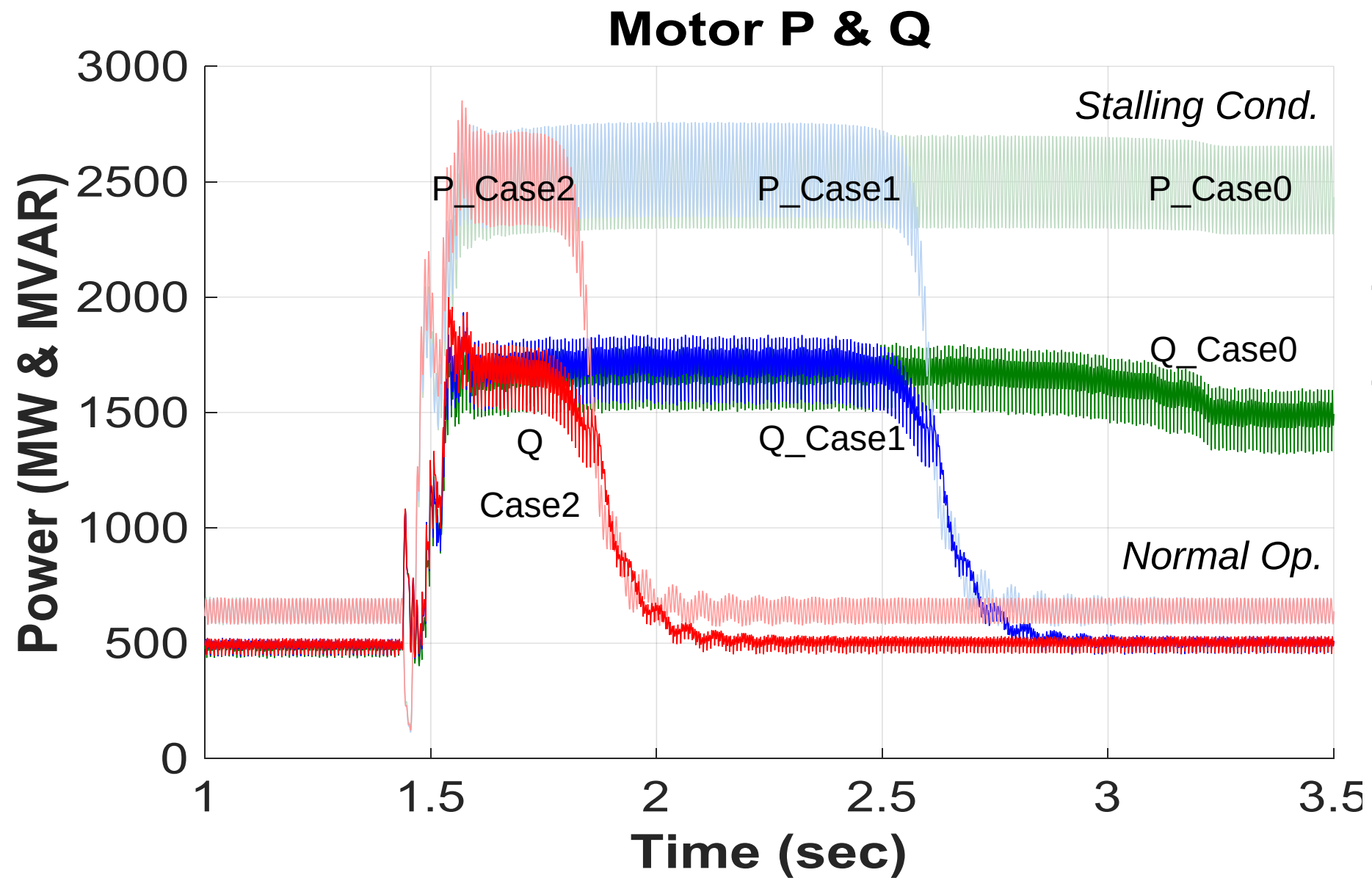


Figure 7. Motor Active (P) and Reactive (Q) Power

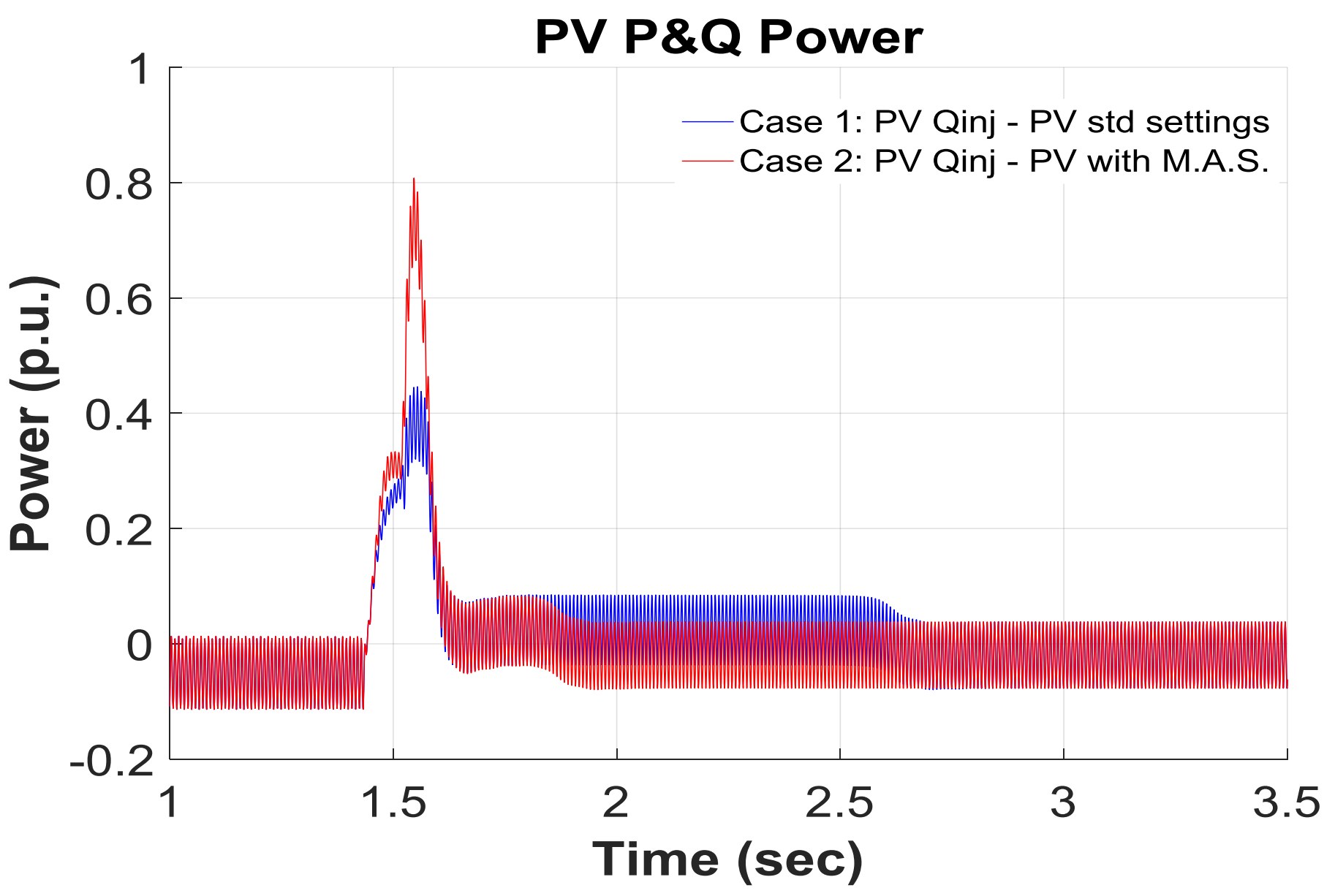


Figure 8. PV Reactive Power Injection

Case 2 (red) shows how the M.A.S. controlled the aggressiveness of the PV controller during the fault condition. In Figure 8 can be observe how the reactive power contribution (red) was incremented two times respect to the standard settings (blue), causing a faster motor recovery, from 1.2 to 0.5 seconds (30 cycles) and thus, an enhancement in the voltage stability as observed in Figure 5 (red).

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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